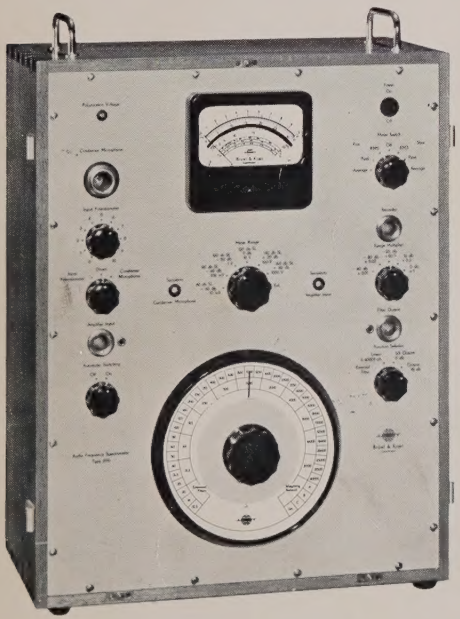
2112

INSTRUCTIONS AND APPLICATIONS

Audio Frequency Spectrometer Type 2112



1/3 and 1/1 Octave Band-Pass Filters.
22—45000 c/s Selective Frequency Coverage.
Standardized Weighting Networks "A", "B", and "C".
RMS, Average and Peak Measurement.
Condenser Microphone Connection.

- Accelerometers
- Acoustic Standing Wave Apparatus
- Artificial Ears
- Artificial Voices
- Audio Frequency Response Tracers
- Audio Frequency Spectrometers
- Audio Frequency Vacuum-Tube Voltmeters
- Automatic A. F.Response and Spectrum Recorders
- Automatic Vibration-Exciter Control Generators
- Band-Pass Filter Sets
- Beat Frequency Oscillators
- Complex Modulus Apparatus
- Condenser Microphones
- Deviation Bridges
- Distortion Measuring Bridges
- Frequency Analyzers
- Frequency Measuring Bridges
- Hearing Aid Test Apparatus
- Heterodyne Voltmeters
- Level Recorders
- Megohmmeters
- Microphone Accessories
- Microphone Amplifiers
- Microphone Calibration Apparatus
- Mobile Laboratories
- Noise Generators
- Noise Limit Indicators
- Pistonphones
- Polar Diagram Recorders
- Preamplifiers
- Precision Sound Level Meters
- Recording Paper
- Strain Gage Apparatus and Accessories
- Surface Roughness Meters
- Variable Frequency Rejection Filters
- VHF-Converters
- Vibration Pick-ups
- Vibration Pick-up Preamplifiers
- Wide Range Vacuum Tube Voltmeters

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BB 2112

Audio Frequency Spectrometer

Type 2112

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0. Introduction

The Audio Frequency Spectrometer is a very versatile measuring instrument which can be employed in a great variety of fields. Predominantly, however, these are covered by acoustics, mechanics and electronics. A brief summary of the most common but important terms concerning these fields are given in the introduction.

Acoustics.

Sound.

A sound in its simplest form can roughly be defined as a rapid variation in air (gases) pressure (or equal variations occurring within other media). A rapid succession of identical pressure variations with equal intervals results in a tone. If the waveform of these variations is sinusoidal, the result is a pure tone. On the other hand, a succession of pressure variations which are

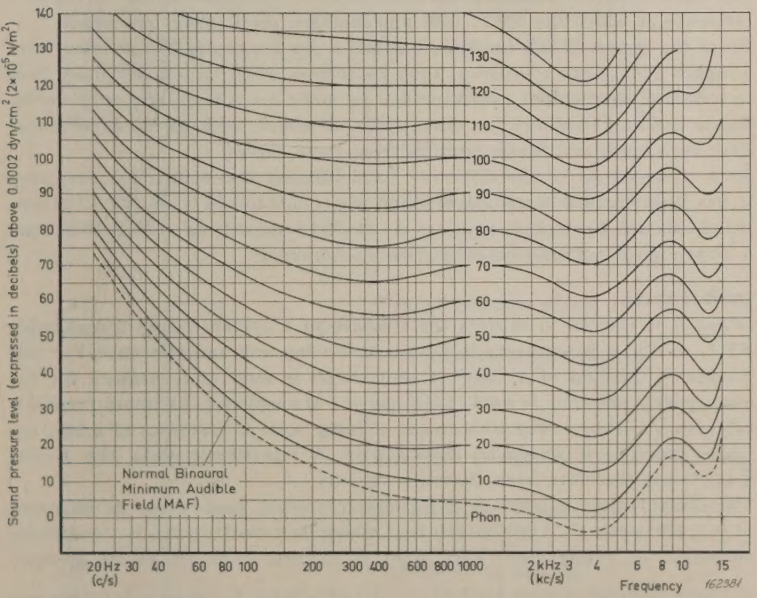

Fig. 0.1. Frequency response of the human ear.

not identical in magnitude or interval will produce a sound normally termed as noise.

Sound Pressure Level (S.P.L.). The Sound Pressure Level of a sound is the r.m.s. (root mean square) value of the magnitudes of the rapid variations in air (gases) pressure when measured objectively by means of a linear measuring instrument. Normally it is given in dB above an r.m.s. reference pressure of 2×10^{-4} μbar.

Sound Level (S.L.). The Sound Level indicates the frequency weighted S.P.L. measured objectively with an instrument containing certain weighting networks which were originally meant to approximate the response of the human ear. The frequency responses of three such weighting networks are internationally standardized (IEC) and have been termed "A", "B" and "C" respectively. As the response of the human ear to sound is a very complicated function, which depends on the frequency as well as the strength of the sound, it has not been possible to give any instrument all the necessary characteristics to "measure" sound subjectively. However, from thorough investigations carried out by various investigators, some general trends can be found. The standardized curves of equal loudness are shown in Fig. 0.1 and refer to tests with pure tones (sine-waves). The 1000 Hz (c/s) serves as a reference at which the S.P.L. (dB) and loudness level (phon) are equal.
From the curves it can be observed that a low-frequency sound must have a higher S.P.L. than a sound of 1000 Hz (c/s) in order to sound equally loud to a human ear. Similar reasoning can be made for a high-frequency sound. Equal loudness contours for other types of sound, such as bands of noise, have been made and found to differ from these curves.
As a consequence of the difficulty in simulating the human ear response, it has been decided to standardize the above mentioned A, B and C curves, which should be looked upon as a standard measuring tool rather than a close approximation to a subjective measurement.

Decibel Scale.
When it is desired to express the strength of a certain sound for example S.P.L. or S.L. it is necessary to have a measuring unit and reference. For this purpose a fraction of a "bar", a unit which is used as a measure for the atmospheric pressure, is used (1.013 bar = 1 atmosphere). As sound pressures often vary within a very wide range, a linear scale in fractions of a bar, e.g. μbars (microbars) would be inconvenient. A logarithmic scale, the decibel scale,*) has therefore been chosen.
The decibel scale, as used in sound measurements, mainly has its reference at 2×10^{-4} μbar (1 / 5 000 000 000 bar) which, at 1000 Hz (c/s), is the hearing threshold of young men. This point is defined as 0 dB sound pressure

*) 1 bel = 10 decibel = 10 dB. For S.P.L. or S.L.: $dB = 20 \log_{10} \frac{p}{p_0}$, where p_0 is the reference pressure.

(p_0). Levels are thus measured in dB relative to 2×10^{-4} μbar. A sound which is a million times greater, i.e. 120 dB on the decibel scale, than that which is the lowest to be heard, is close to the so-called pain threshold of a human ear. It is thus obvious, that the range of sound pressure levels normally of interest, may be covered by a decibel scale containing 120 linear graduations. The decibel scale offers a relative scale with equal degrees of reading accuracy throughout the complete range. This would not be the case for a linear scale which would contain one million divisions.

In the table below, a few well-known sound phenomena are located on the decibel scale, and parallel to this a scale of micro- and millibars in order to give the inexperienced reader an idea in the use of these scales.

Sound pressure in bar	Sound level in dB		Environmental conditions
		140	
1 mbar	134		Threshold of pain
		130	Pneumatic Chipper
		120	
100 μbar	114		Loud automobile horn (dist. 1 m)
		110	Inside airliner (DC 6)
		100	
10 μbar	94		Inside subway train (New York)
		90	Inside motor bus
		80	
1 μbar	74		Average traffic on street corner
		70	Conversational speech
		60	
0.1 μbar	54		Typical business office
		50	Living room, suburban area
		40	
0.01 μbar	34		Library
		30	Bedroom at night
		20	
0.001 μbar	14		Broadcasting studio
		10	
0.0002 μbar		0	Threshold of hearing

Octave.

When dealing with acoustics, an octave is an expression of a relative measure of frequency, i.e. 1 octave above or below a certain frequency f_0 means $2 \times f_0$ or $\frac{1}{2} \times f_0$ respectively.

Mathematically it is expressed by:

$$\frac{f}{f_0} = 2^n$$

where n may be positive, negative, a fraction or a number of octaves and f_0 the frequency to which the frequency f is referred.

By taking the logarithm on both sides of the equation above, it is derived:

$$\log_{10} \frac{f}{f_0} = n \times 0.3010$$

from which f or n for a given n or f respectively can be calculated.

In Fig. 0.2 will be found a graph where n, positive and negative, is plotted versus relative frequency $\frac{f}{f_0}$.

Example:

$+\frac{3}{6}$ octave = + 0.5 octave
reads $\frac{f}{f_0} = 1.41$

$-\frac{1}{6}$ octave = — 0.17 octave
reads $\frac{f}{f_0} = 0.89$

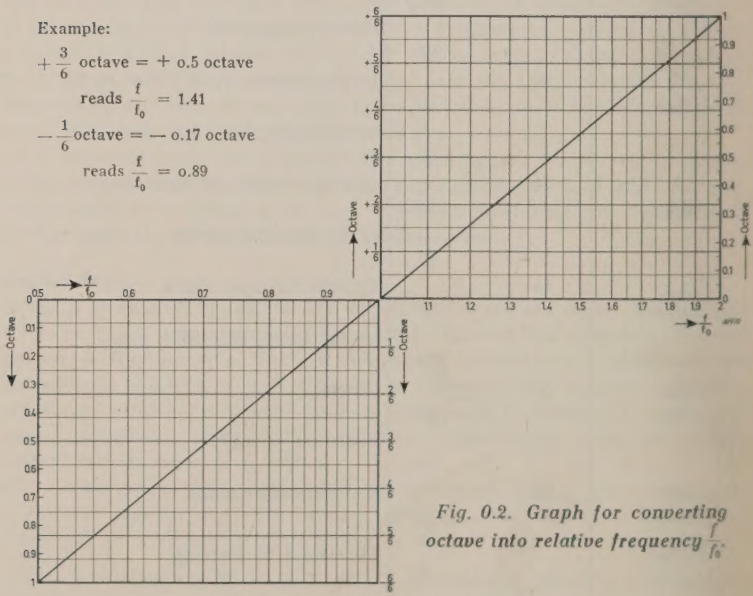

Fig. 0.2. Graph for converting octave into relative frequency $\frac{f}{f_0}$.

Vibration.

In mechanical vibration three quantities are often dealt with, displacement (movement) s, velocity v and acceleration a. The relation between the three quantities is as given in the following table. For sinusoidal vibration the relation is as printed in small type.

Given Quantity:—	Transferred to—		
	s	v	a
s $s = S_o \sin(\omega t)$		$v = \frac{ds}{dt}$ $v = \omega S_o \cos(\omega t)$	$a = \frac{d^2s}{dt^2}$ $a = -\omega^2 S_o \sin(\omega t)$
v $v = V_o \sin(\omega t)$	$s = \int v dt$ $s = -\frac{1}{\omega} V_o \cos(\omega t)$		$a = \frac{dv}{dt}$ $a = \omega V_o \cos(\omega t)$
a $a = A_0 \sin(\omega t)$	$s = \iint a dt^2$ $s = -\frac{1}{\omega^2} A_o \sin(\omega t)$	$v = \int a dt$ $v = -\frac{1}{\omega} A_o \cos(\omega t)$	

In the m.k.s. measuring system the units will be

s in m
v in m/sec.
a in m/sec.^{2}

Frequently a is expressed in the unit G which is the acceleration derived from the gravitational force of attraction of the earth. As the gravity alters with latitude and altitude a standard gravity is chosen as $G = 9.80665$ m/sec.^{2} = 32.1739 ft/sec.^{2}.

Types of Noise.

Audible noise is generally defined as "unwanted sound". This definition refers to everyday life and may, even then, not be strictly correct. The elimination of all background noise would, for example, result in a certain feeling of discomfort, and the definition therefore applies to noise above a certain loudness level. Some particular forms of controlled audio frequency noise are also "wanted" because they are very useful for acoustic and electro-acoustic measurement purposes. This is the case, for example, with the so-called white Gaussian random noise.

Random noise may be defined as a signal whose instantaneous magnitude is not specified for any given instant of time. The instantaneous magnitude

of random noise is specified only by probability distribution functions which give the fraction of the total time that the magnitude, or some sequence of magnitudes, lies within a specified range.

Gaussian random noise is a random noise signal, the magnitude of which is distributed according to the Gaussian (normal) distribution function.

White Gaussian random noise is a Gaussian random noise signal, the frequency spectrum of which is continuous and uniform, thus containing equal power per cycle bandwidth in the band considered.
A noise signal which is both white and Gaussian random will, when used for the excitation of objects under investigation, in many cases simulate the effect that would be expected in environments determined by the laws of nature. It is therefore a powerful tool in such investigations. However, even if the excitation of test objects by a wide band of white noise may give much useful information, it is often required to utilize the noise in narrower bands. Measuring equipment designed to handle white noise will therefore often include a selective apparatus, as well as a noise generator which produces such a signal. The B & K "AUDIO FREQUENCY SPECTROMETER TYPE 2112" serves as an excellent selective section in such measuring equipment. The Spectrometer can be used both as the transmitting section, selecting signals, in narrow bands, from the noise generator, or as a selective indicator.

Filters Handling White Noise.

In investigations where narrow bands are to be selected from white noise the use of band-pass filters is necessary. Ideally such filters should display zero attenuation within the pass-band and infinite attenution elsewhere, i.e. filters which provide rectangular amplitude vs. frequency characteristics. Refer also Fig. 0.3. Such filters cannot be produced in practice by passive components but, they should display characteristics as near as possible to that of the ideal filters, i.e. a flat pass-band and steep skirts.

Effective Bandwidth of a practical filter is equal to the bandwidth of an ideal filter which has uniform transmission in its pass-band equal to the maximum transmission of the specified filter and transmits the same power of white noise as the specified filter.
The effective bandwidth of a specified filter can be determined by firstly plotting the amplitude vs. frequency response of the filter in a graph with a linear ordinate showing the ratio, transmission at the particular frequencies to the maximum transmission, and with an abscissa showing the relative frequency $\frac{f}{f_o}$, where f_o equals the center frequency of the filter. Refer also Fig. 0.3. Sceondly, the ordinates of this characteristic are now squared and plotted in the same co-ordinates as above. Thirdly, the area so enclosed by the new characteristic and the zero line (hatched in Fig. 0.3) divided by

maximum height of same area gives the effective bandwidth of the specified filter.

In many noise measurements it is convenient to know the correction factor in dB for the individual filters which have to be applied to the measured quantities, due to the fact that the practical filters do not have a characteristic identical to the ideal filter. This correction factor can be derived from the effective bandwidth of the individual filters as this is a measure of the noise power the filter allows to pass.

$$\text{Correction Factor (dB)} = 10 \times \log \frac{\text{Effective Bandwidth}}{\text{Bandwidth of Ideal Filter}}$$

When relative noise measurements are made, it is also of great convenience to know how much this correction factor deviates from filter to filter. The deviation in the factor could, additionally, be referred to a filter in the middle of the range, for example at 1000 Hz (c/s).

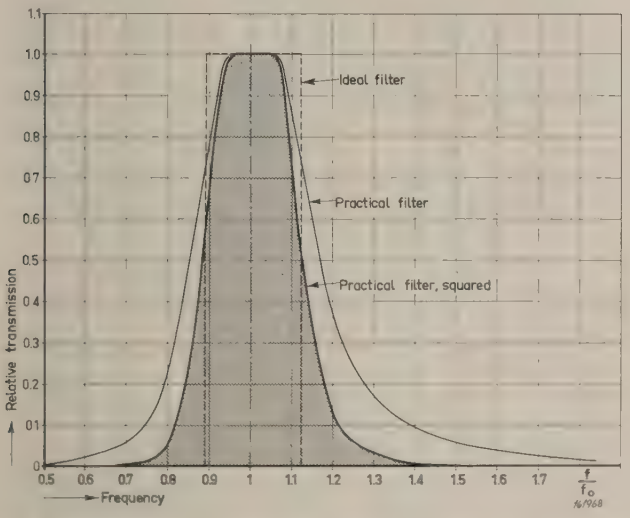

Fig. 0.3. Characteristics of an ideal and practical filter. Note both co-ordinates are linear.

If the deviation of the correction factor was zero (which, of course, will be impossible for practical filters), and the filters in the range considered display constant relative bandwidth, the output noise level from the filters would increase by exactly 10 dB/decade $\simeq$ 3 dB/octave, as the RMS voltage of white noise is proportional to the square-root of its effective bandwidth. The deviation in the correction factor of the individual filters will thus equal the deviation, which can be expected from this 3 dB/octave line.

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1. Description

General.

The Audio Frequency Spectrometer Type 2112 is primarily designed for analysis in the fields of acoustics, electro-acoustics, and vibration in the frequency range 22—45000 Hz (c/s). Basically it consists of an input amplifier, a filter system of band-pass filters and weighting networks, and an output amplifier as shown in the block diagram Fig. 1.1.

The bandwidth of the band-pass filters is ⅓ and 1/1 octave respectively, which makes the instrument well-suited for the frequency analysis of noise and vibration signals, as well as for selective measurements. These filters may be selected manually or electro-mechanically. The latter method is performed by a built-in electromagnetic device, which can be externally operated. By controlling the switching from the B & K Level Recorder, Type 2305, it is possible to automatically record spectrograms on preprinted, frequency calibrated recording paper.

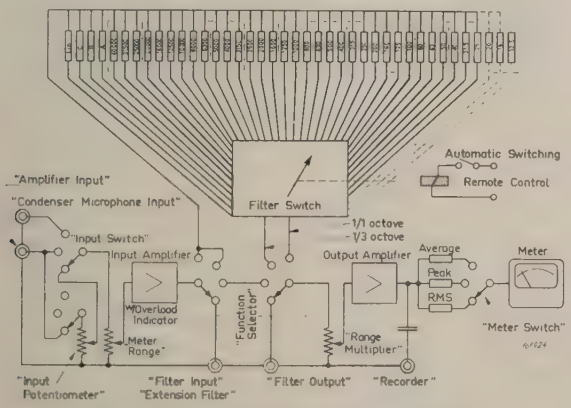

Fig. 1.1. Block diagram of Spectrometer.

When equipping the Spectrometer with one of the B & K Condenser Microphones having free field characteristics, the complete equipment fulfills the international standards for Precision Sound Level Meters*) as the

*) As discussed at the International Electrotechnical Commission (I.E.C.) TC 29 in Helsinki 1961.

Spectrometer includes weignting networks giving the curves "A", "B" and "C". When switched to "Lin. 2—40ooo nqyETAOI ETAOIN ETAOIN ATOIN the Spectrometer is linear from 2 Hz (c/s) to 45ooo Hz (c/s).
The indicating meter is equipped with three different rectifier circuits which enable the true r.m.s. value, the average absolute value, known as average value, and half the peak-to-peak value of the signal to be measured. The power supply contains the necessary rectifiers for operation of the amplifiers, and also for operating the B & K Condenser Microphones or Vibration Pick-up Preamplifier, whichever is required.

Input Amplifier.

Input Circuit. The input amplifier consists of three stages. It is provided with two different input sockets, one of which (CONDENSER MICROPHONE) is seven-pinned corresponding to the plug on the B & K Condenser Microphones and Preamplifiers. The other (AMPLIFIER INPUT) accommodates a 14 mm coaxial plug which can be connected to the input circuit of the amplifier, either directly or via a variable potentiometer used for relative measurements.
By means of a three-position INPUT SWITCH marked "Input Potentiometer", "Direct", and "Condenser Microphone" three input facilities can be chosen. When the input socket marked CONDENSER MICROPHONE is used the input switch has to be in position "Condenser Microphone". When the AMPLIFIER INPUT socket is used the input switch may either be in the position "Direct" or in the position "Input Potentiometer". When the continuously variable INPUT POTENTIOMETER is used, it should be noticed that the frequency response is not within the tolerances given in the instrument specification. The deviation is due to the stray capacitance of the potentiometer and is dependent on the setting, refer also Fig. 1.15 on page 29.
The input impedance of the Spectrometer is 2.2 Mohm parallel with 30 pF when the INPUT SWITCH is set to "Direct"*). From this switch the signal voltage is fed to a voltage divider, which is operated by the knob marked METER RANGE, on the front panel, and contains five steps of 20 dB. The different positions are indicated by the values "10 mV" to "1ooo V", "— 60 dB" to "+ 40 dB", and "60 dB S.L." to "160 dB S.L.".

Amplifier Section. The first two stages of the amplifier consist of resistive-capacitive coupled triodes, while the third stage comprises a cathode follower. A large amount of negative feedback is introduced to stabilize the amplifier and to ensure a low source impedance (approximately 10 Ω) to be coupled to the filter system.

*) If a very high input impedance is required, this can be obtained by utilizing one of the B & K Cathode Followers Type 2612, 2613, 2614 or 2615. Refer also specification for Cathode Followers in part Accessories page 72.

A terminal on the rear of the instrument marked FILTER INPUT - EXTENSION FILTER enables either the input amplifier to be used separately, or a B & K Extension Filter Set Type 1620 to be connected. The Extension Filter Set extends the frequency range of selective measurements down to 11 Hz (c/s).

Overload Indicator: The output of the input amplifier is paralleled by an OVERLOAD INDICATOR. The indicator is so designed that it gives a visual indication when signal peak voltages exceed 4.5 V on the output of the input amplifier. The signal to be monitored is amplified in a triode connected pentode and fed to a gas tube, indicating overload by a red light. Refer also to item "Overload and Clipping" on page 31.

Filters.

With the switch FUNCTION SELECTOR it is possible to select sets of filters, either with a bandwidth of ⅓ octave, or with a bandwidth of 1/1 octave. The center frequencies of both types of filters are placed in accordance with the ISO standards for acoustic measurements.

1/3 OCTAVE FILTERS

Design. The Spectrometer is equipped with 33 filters having center frequencies as given in the table below from which the filter bandwidth in cycles per second can also be found.

Center Frequency Hz (c/s)	Bandwidth at 3 dB Hz (c/s) Approx.	Center Frequency Hz (c/s)	Bandwidth at 3 dB Hz (c/s) Approx.
25	5.8	1000	230
31.5	7.3	1250	290
40	9.2	1600	370
50	11.6	2000	460
63	14.6	2500	580
80	18.3	3150	730
100	23	4000	920
125	29	5000	1160
160	37	6300	1450
200	46	8000	1830
250	58	10000	2300
315	73	12500	2900
400	92	16000	3700
500	116	20000	4600
630	145	25000	5800
800	183	31500	7300
		40000	9200

A single filter consists of three resonant circuits coupled together as shown in Fig. 1.2. The first two resonant circuits have a quality factor Q of approx-

imately 10, and their coupling factor k is of the order of o.2. The third resonant circuit has a Q of approximately 5 and is coupled loosely to the two first circuits (k = o.05 approx.).

The first two circuits will give rise to a two-topped frequency response, as shown in Fig. 1.3 left. The third gives a single top which raises the valley between the two tops, so that a resultant curve having a relatively flat band-pass and steep sides as shown in Fig. 1.3 right is obtained. Because the quality factor is dependent on the frequency, the two tops will not have the same height. To obtain the desired band-pass, the third resonant frequency must therefore be placed unsymmetrically, and the resultant response curve will have two humps, a broad one and a narrow one.

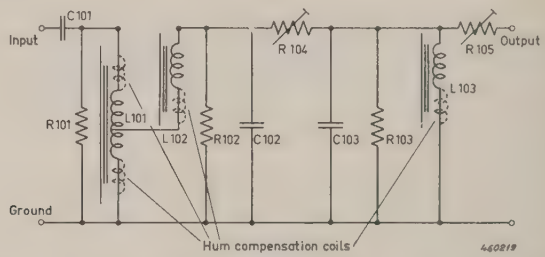

Fig. 1.2. Schematic diagram of a single ⅓ Octave Filter unit.

The input impedance response of all the filters will be a wave-shaped curve, varying between approximately 500 ohms and 2ooo ohms, so that the impedance is high at the center frequencies and low at the band limits. The input voltage will therefore also vary up and down if the output impedance of the input amplifier is not made low. In the Spectrometer an output impedance of approximately 10 ohms has been obtained. The voltage across the filters will thus only vary approximately 1.5 %.

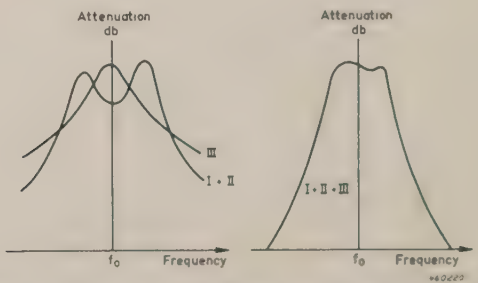

Fig. 1.3. Frequency characteristics illustrating the function of a ⅓ Octave Filter unit.

To keep the transients in the filters to a minimum all the filter inputs are coupled in parallel. Furthermore, the filters are pre-loaded, and the change in load—when the Filter Switch connects the output amplifier to the different filters—is thus negligible.

Frequency Response. The frequency response of a filter is flat to within ± ½ dB over approximately ¼ octave. At the band limits, i.e. ⅙ octave from the center frequency, the attenuation is approximately 3 dB. See Fig. 1.4. However, due to the rather steep slope of the filter curves at these points, the frequency characteristics of two neighbouring filters cannot be expected to intersect exactly at the 3 dB point. This is easy to understand, because a displacing of the center frequencies of the two filters by only 1 % in opposite directions, will cause the intersection to take place at a point 1.7 dB higher or lower than the 3 dB point. If the width of one filter curve is changed by 1 %, the point of intersection is changed by 0.2 dB.
The attenuation approximately at ± ⅓ octave from the center frequency is 20 dB, and at ± 1 octave 52 dB. It has been impossible to obtain sufficiently

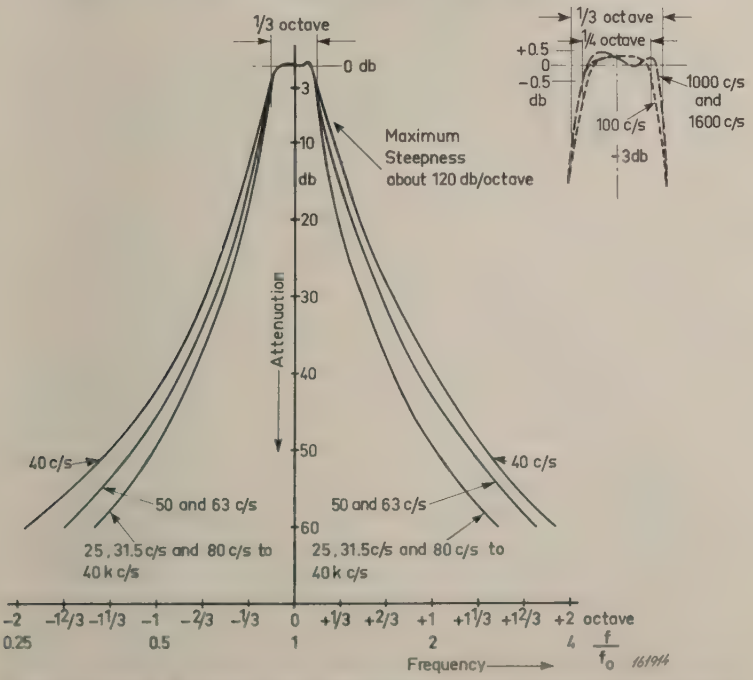

Fig. 1.4. Detailed ⅓ Octave Filter characteristics derived from sine-wave signals

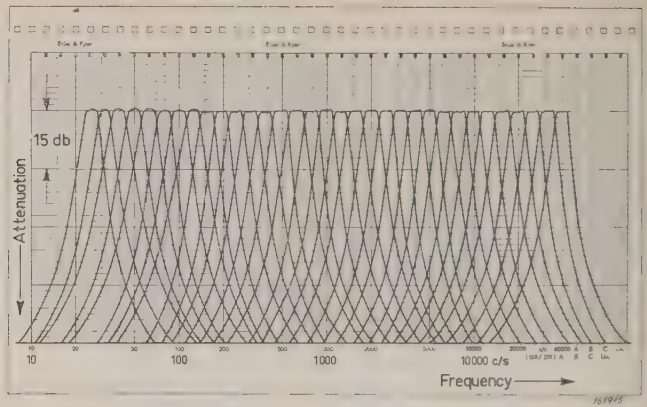

Fig. 1.5. Complete set of filter characteristics when Spectrometer is in ⅓ Octave condition.

high quality factors for the coils at some frequencies below 80 Hz (c/s) without lowering the stability or making the filters larger and heavier. The filter curves will therefore not be of the same quality at these frequencies, as there will be only one top, and the "flat" part is about ⅙ octave wide. The attenuation of these filters is up to 4 dB at the band limits, from 14 to 20 dB at ± ⅓ octave, and from 42 to 50 dB at 1 octave away from the center frequency.

Effective Bandwidth. The effective bandwidth*) of the ⅓ octave filters is 9 % greater than the bandwidth of an ideal ⅓ octave filter of which the transmission in the pass band is equal to that of the Spectrometer when in condition "Linear, 2—40000 c/s". Due to tolerances in the filter production, the mentioned correction of + 9 % to the bandwidth may be found to lie between 0 % and + 20 %.

In some measurements it may be necessary to make a correction to the measured values because of the 9 % greater bandwidth. The correction factor*) in dB then equals —0.4 dB. The deviation of this factor will, due to the production tolerances be ± 0.1 dB, which means that the greatest relative deviation will be within ± 0.4 dB.

Phase Response. Due to the nature of the filters they will cause a phase distortion, which is shown in Fig. 1.6, together with the amplitude response of the filter top. The hatched area indicates the limits within which the different filter curves for one apparatus are expected to lie.

Hum Compensation. To reduce the induction of hum, in some of the low frequency filters, occuring from magnetic fields created by nearby mains.

*) Vide also Introduction, para Types of Noise.

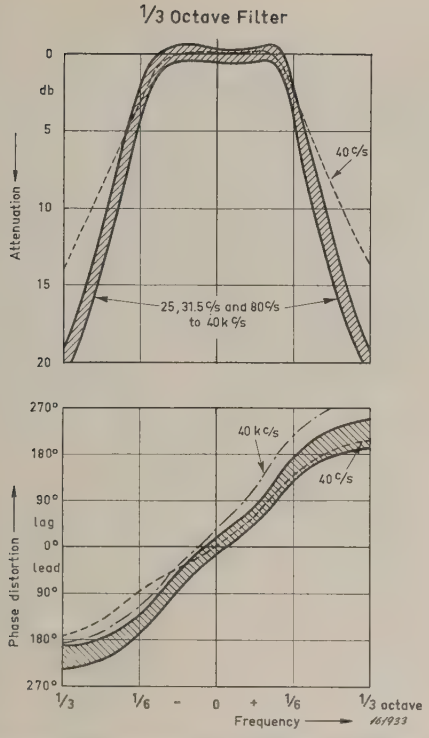

Fig. 1.6. Phase response of Spectrometer in ⅓ Octave condition, shown together ***with the respective amplitude characteristics.***

transformers, or electrical machinery, the filters are provided with hum compensation coils as seen in Fig. 1.2. By this means a very low hum level is obtained.

1/1 OCTAVE FILTERS

Design. The 1/1 octave filters are obtained by internally combining the ⅓ octave filters in units of three, in such a manner that the bandpass of the individual units will cover a complete octave. The center frequencies of the octave filters are given in the table, together with the filter bandwidth. Due to the circuit used for connecting three ⅓ octave filters into a 1/1 octave filter a certain voltage drop is unavoidable. This voltage drop is made equal to 10 dB, which should be taken into account during measurements. The FUNCTION SELECTOR switch is therefore in position "Octave" also marked "10 dB".

Center Frequency Hz (c/s)	Bandwidth at 3 dB Hz (c/s) Approx.	Center Frequency Hz (c/s)	Bandwidth at 3 dB Hz (c/s) Approx.
31.5	22	2000	1406
63	45	4000	2805
125	89	8000	5597
250	177	16000	11170
500	353	31500	22280
1000	702		

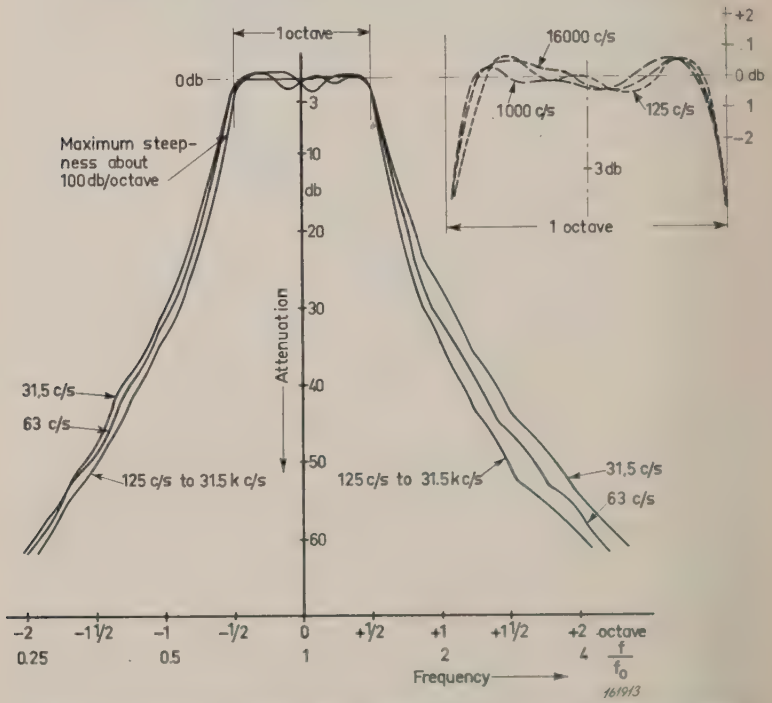

Fig. 1.7. Detailed ⅓ Octave Filter characteristics derived from sine-wave signals.

Frequency Response. The filters are adjusted so that the deviations in the pass band between peaks and valleys are within ± 1 dB; for the 31.5 Hz (c/s) and 63 Hz (c/s) within ± 2 dB. At the band limits, i.e. ± ½ octave from the center frequency, the attenuation is approximately 3 dB, vide Figs. 1.7 and 1.8.

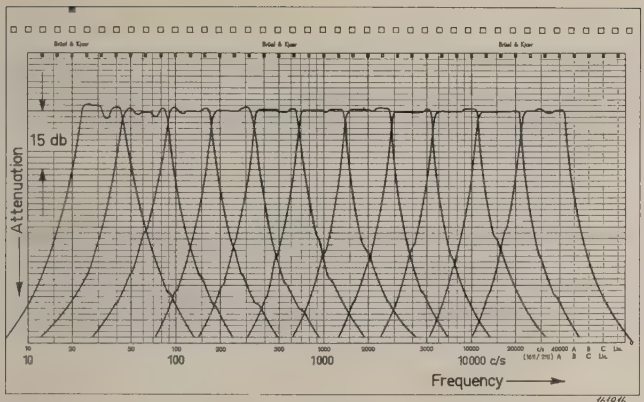

Fig. 1.8. Complete set of filter characteristics when Spectrometer in 1/1 Octave condition.

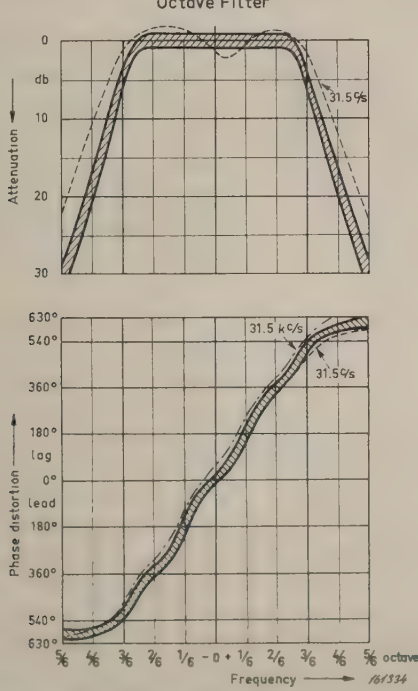

Fig. 1.9. Phase response of Spectrometer in 1/1 Octave condition shown together with the respective amplitude characteristics.

The attenuation at ± 1 octave is approximately 35 dB, being somewhat less for the filters at the lower frequencies.

Phase Response. The phase response curves of the octave filters are shown in Fig. 1.9, together with the amplitude response of the filter top. The curves for the different filters are expected to lie within the hatched area.

Weighting Networks.

"A", "B" and "C". Sound Pressure Level measured by the Spectrometer can be weighted in accordance with the I.E.C. standards by switching in the three weighting networks "A", "B" and "C". The networks are mainly designed as illustrated in Fig. 1.10. The frequency response, related to each sinusoidal component of the sound pressure, is given in Fig. 1.11. In the table below

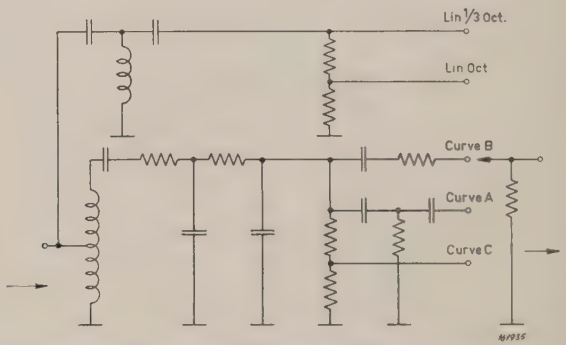

Fig. 1.10. Schematic diagram of Weighting Networks for sound level measurements.

Frequency Hz (c/s)	10	20	40	80	160	315	630	1000	2000	4000	8000	12500	20000	
Curve A	—70.5	—50.4	—34.6	—22.4	—13.3	—6.6	—1.9	0	1.2	1.0	—1.1	—4.1	—9.2	dB
Curve B	—38.5	—24.4	—14.3	—7.4	—3.0	—0.9	—0.1	0	0.1	—0.7	—2.9	—6.0	—11.0	dB
Curve C	—15.5	—6.3	—2.0	—0.5	—0.1	0	0	0	—0.2	—0.8	—3.0	—6.2	—11.1	dB
Tolerance														
Precision Sound Level Meters IEC standard	**+5 —∞**	**+5 —5**	**+3 —3**	**+2 —2**	**+1 —1**	**+1 —1**	**+1 —1**	**+1 —1**	**+1 —1**	**+1 —1**	**+1.5 —1.5**	**+3 —3**	**+3 —6**	**dB dB**
Tolerance														
Ordinary Sound Level Meters IEC standards	**+5 —∞**	**+5 —∞**	**+4.5 —4.5**	**+3.5 —3.5**	**+3 —3**	**+3 —3**	**+3 —3**	**+2 —2**	**+3 —3**	**+5.5 —4**	**+6 —6**	**+6 —∞**	**+6 —∞**	**dB dB**

will be found the tolerances required by the proposed I.E.C. standards for Precision Sound Level Meters (Helsinki 1961). The Spectrometer, equipped with one of the B & K Condenser Microphones Type 4131 or 4133, will, when set for Sound Level measurements, be within these tolerances. For comparison the I.E.C. tolerances for ordinary Sound Level Meters are also given.

When employing the weighting networks it should always be stated together with the measured result which of the curves has been utilized during the investigation. Example: S.L. 86 dB (B).

Low Frequency Cut-off. In various measurements it is convenient to cut off frequencies below 20 Hz (c/s), for this purpose a special weighting network "Lin" can be selected. The frequency characteristic can be seen in Fig. 1.11, where the cutting off, which is 18 dB per octave, is clearly seen.

In position "Octave, 10 dB" of the FUNCTION SELECTOR the output signal from both types of weighting networks are attenuated 10 dB equal to the signal derived in the pass band of the octave filters.

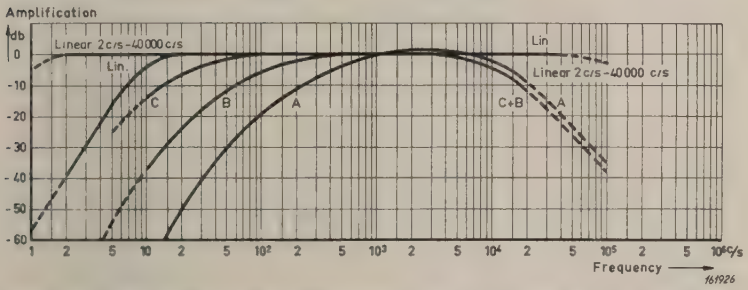

Fig. 1.11. Typical frequency characteristics "A", "B" and "C" for sound level measurements. Valid for the Spectrometer equipped with one of the Condenser Microphones Type 4131 or Type 4133. Curves also plotted for "Linear, 2—40000 c/s" and "Lin" (20—45000 Hz (c/s)) characteristics.

Selection of Filters and Weighting Networks.

The successive switching of the filters and weighting networks is accomplished by the FILTER SWITCH (see Fig. 1.1). The center frequency and respective type of weighting network are indicated on a large illuminated scale. The ⅓ octave filters and weighting networks are marked on the outer part, and the 1/1 octave filters on the inner part of the scale. The scale is calibrated from 12.5 Hz (c/s) to 40 kHz (kc/s), although the Spectrometer does not contain filters with center frequencies lower than 25 Hz (c/s). The additional calibration on the scale is based on the use of the Extension Filter Set Type 1620 (ZS 0146). Calibrations "A", "B" and "C" towards the end of the scale refer to the positions of the FILTER SWITCH when the weighting

networks are inserted between input amplifier and output amplifier. A final calibration "Lin" refers to a special weighting network making the frequency characteristic of the complete Spectrometer flat from 20 to 45000 Hz (c/s).

Remote Control: The FILTER SWITCH can be manually or automatically operated, the latter being achieved by a remotely controlled electro-magnetic drive unit. To obtain remote control an external DC supply (24 V, 180 mA) in series with a single-poled switch is required. The connections to be made to the jack REMOTE CONTROL can be seen in Fig. 1.12.

NOTE: Take care that the + terminal of the external DC source is connected with pin 2 and the — terminal with pin 1. If inversely connected a spark-suppressor diode will be damaged.

When the switching action is controlled from the Level Recorder Type 2305 a special cable AQ 0002 has to be applied between the two instruments.

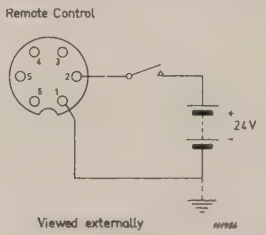

Fig. 1.12. Connection of "Remote Control" for remote control of the Filter Switch.

Extension Filters. The rotary switch has 50 positions. One complete revolution of the switch thus means 50 successive switchings. Only 37 positions of the 50 are employed for the connections to the built-in filters and weighting networks, 13 positions thus being unused. These 13 points are connected to a terminal board at the back of the instrument chassis (vide Fig. 4.3 on page 67), and can, when desired, be used for connection of additional external filters. Three of these points are already led to the seven pin socket marked FILTER INPUT - EXTENSION FILTER, to which the above mentioned Extension Filter Set Type 1620 can be connected. The Filter Set is available as a separate unit and consists of three filters with a bandwidth of $\frac{1}{3}$ octave and center frequencies of 12.5—16 and 20 Hz (c/s). In addition, a $\frac{1}{1}$ octave condition with a center frequency of 16 Hz (c/s) is also obtainable. When Type 1620 is not used, or when it is built into the cabinet of the instrument (ZS 0146) a special adaptor is inserted in the FILTER INPUT - EXTENSION FILTER jack, transforming the seven-pin jack into a 14 mm screened coaxial socket, the adaptor then provides a connection to the output of the input amplifier. Note should be made that the built-in method only applies to Type 3315 and 3332.

Output Amplifier.

Input Circuit. The output amplifier consists of three stages and has an input impedance of 1.46 MΩ.

A voltage divider in the input circuit contains four steps of 10 dB and is operated by the knob marked RANGE MULTIPLIER. With the RANGE MULTIPLIER switch in position "x 1, 0 dB" the amplification of the output amplifier is 10 times (20 dB). Maximum amplification is obtained with the RANGE MULTIPLIER switch in position "x 0.01, — 40 dB" and is then 1000 times (60 dB).

Sensitivity Adjustment. The output amplifier is provided with negative feedback, the amount of which may be varied by two potentiometers. By this means the sensitivity of the apparatus can be adjusted and thereby calibrated. One of the potentiometers is in circuit when the INPUT SWITCH is in position "Condenser Microphone", the other when the switch is in either of the two positions "Direct" or "Input Potentiometer". Separate sensitivity adjustment is therefore obtainable for sound and voltage measurements, this being an additional convenience during practical use of the Spectrometer. The potentiometers can be adjusted with a screwdriver through holes in the front panel, which are marked SENSITIVITY — CONDENSER MICROPHONE and SENSITIVITY — AMPLIFIER INPUT respectively.

Output. The output circuit of the amplifier is connected both to the output sockets marked RECORDER and to the rectifier and meter circuit. The RECORDER terminal is provided for connection to headphones, oscillograph, level recorder etc. The output impedance at this terminal is equivalent to a resistor of 50 Ω in series with a condenser of 24 μF. Any load connected to the RECORDER output should have as high an impedance as possible, preferably not less than 3 kΩ.

Output Voltage. When the instrument meter gives full deflection, an AC voltage of 8—10 Volts is available across the RECORDER socket.
The amplifiers in the Spectrometer are constructed in such a way that they do not clip the signal, if its peak value, after amplification in the output stage, does not exceed a value of 13 dB higher than is indicated for full deflection on the meter, i.e. 10 Volts + 13 dB ≅ 45 Volts peak with unloaded "Recorder" output.

Rectifier and Meter Circuit.

A switch in the rectifier circuit marked METER SWITCH enables either the true r.m.s., the average absolute value, known as average value, or half the peak-to-peak value of the input signal to be measured by the moving coil instrument.

R.M.S. Measurements. The characteristic of an instrument designed to measure the r.m.s. value, should be parabola. By a specially constructed circuit of resistors and semiconductor diodes this parabola is simulated. The rectifier circuit employed is a full-wave rectifier and the combined circuit is developed to measure the r.m.s. value of signals with crest factors f_c as high as 5.

$$f_c = \frac{S_{rms}}{S_{peak}} = 5$$

However, due to the peak limiting (45 Volts) of the output amplifier in the Spectrometer, the highest deflection for r.m.s. value of the meter pointer when measuring signals with crest factors 5, should not exceed:—

$$S_{rms} = \frac{S_{peak}}{f_c} = \frac{45}{5} = 9 \text{ Volts.}$$

For full deflection the crest factor f_c should not exceed:—

$$f_c = \frac{45}{10} = 4.5$$

At low frequencies the meter pointer will start to fluctuate when the METER SWITCH is in the position "Fast". When the fluctuation due to the low frequency is too large, the value read is no longer the correct value. The METER SWITCH should therefore be set in position "Slow". The lower limiting frequency in position "Fast" is approximately 20 Hz (c/s) (sine-wave).

Arithmetical Average Measurements. The circuit employed is a full-wave rectifier, enabling the average value of the complete signal to be measured. Care should be taken not to overdrive the amplifiers when measuring the average value of a complex signal, which has high peaks. It is therefore necessary to know the highest peaks, positive or negative, which occur in the measured signal. By using the two factors, crest factor f_c and form factor f_f,

$$f_c = \frac{S_{peak}}{S_{rms}} \qquad f_f = \frac{S_{rms}}{S_{average}}$$

the peak value of the signal may be calculated, provided the average value (read on the meter) and the two factors are known.

$$S_{peak} = f_c \times f_f \times S_{average}$$

As the 45 Volts peak should not be exceeded, when the meter pointer gives full deflection for average value, the highest permissible value for

$$f_c \times f_f = \frac{45}{10} = 4.5.$$

If the meter pointer does not show full deflection, the product $f_c \times f_f$ could be proportionally higher.

Peak Measurements. The circuit for measuring peak values is a normal full-wave rectifying circuit. The signal from the output amplifier is applied via a condenser C_1, vide Fig. 1.13. Due to this condenser, the deflection on the meter corresponds to the half peak-to-peak value of the signal. That should be taken into account when the positive and negative values of a signal, applied from the output stage, are not equal. In this case, the peak value read on the meter is thus not the maximum that occurs. Also, when measuring complex signals which are phase distorted in the amplifiers, deviation in Peak reading will occur. (Refer Appendix page 112).

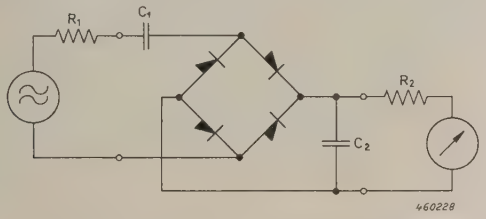

Fig. 1.13. Peak rectifier circuit arrangement.

Referring to Fig. 1.13 the ideal charging resistance, R_1, for C_1 and C_2, which includes the output resistance of the output stage, should be zero and the discharging resistance, R_2, infinite. In practice this is impossible and signals with very thin peaks and high crest factors will be somewhat clipped. However, with the chosen values in the B & K rectifier circuit, even when measuring positive or negative pulses with crest factor 5, the clipping of the signal will be negligible, refer to passage "R.M.S. Measurements". Fig. 1.14 gives an impression of a signal with a crest factor of 5.

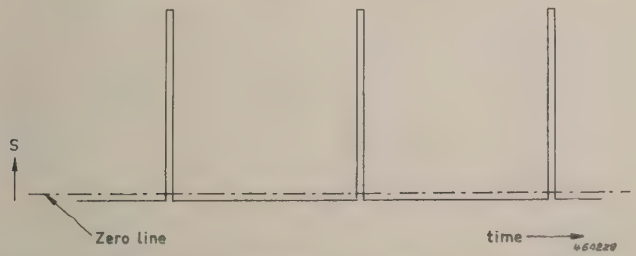

Fig. 1.14. Example of unsymmetrical signal with a crest factor of approximately 5.

At low frequencies, i.e. below 20 Hz (c/s) (sine-waves), the METER SWITCH should be set in position "Slow". The reason is as under "R.M.S. Measurements".

A discription of the working principle of the complete rectifier circuit is given in the B & K Technical Review, No. 3-1958.

Damping and Graduation of Meter. The moving coil instrument is furnished with two different damping characteristics of the meter "Fast" and "Slow" which are in accordance with the proposed standards for Precision Sound Level Meters.
The meter scale is graduated 0—10 and 0—31.5 as well as 0 to 20 dB. Furthermore, scales, permitting the direct reading of acoustic absorption coefficients are provided. These scales should be used when measurements are taken with the Standing Wave Apparatus Type 4002. When utilizing the first three graduations electrical measurements can be read either in mV, volt or in dB re. 1 volt, and acoustical measurements in Sound Pressure Level (S.P.L.) or Sound Level (S.L.) re. 2×10^{-4} μbar. When measuring S.P.L. or S.L. one of the B & K Microphones should be used in conjunction with the Spectrometer. For use of the scales concerning the Standing Wave Apparatus, reference should be made to the instruction book for this apparatus.

Overall Performance of the Instrument.

Frequency and Phase Response. When FUNCTION SELECTOR is set to "Linear, 2—40000 c/s" or "⅓ Octave, 0 dB" and FILTER SWITCH in the latter case set to "Lin" the typical frequency and phase response curves derived are reproduced in Fig. 1.15.
Referring to the frequency response curves it should be noted that when analysing or measuring complex signals containing many significant harmonics the upper limit of the frequency range should be borne in mind as the harmonics above this limit may be attenuated, thus obtaining a wrong measurement. Associated with the two frequency response curves are shown two dotted curves giving the typical characteristics for the Spectrometer when INPUT SWITCH is set to "Input Potentiometer". The curves give the highest deviation from the linear characteristics (INPUT SWITCH on "Direct") achieved for all different positions of "Input Potentiometer". In spite of the deviation from the linear response above 5000 Hz (c/s) the "Input Potentiometer" can always be utilized above this frequency for relative measurements of signals containing equal frequency spectrum.
Common amplifiers show a phase distortion which is perceptible a decade or more higher than the lower limit frequency and a decade or more lower than the highest limit frequency. This phase distortion especially influences the peak value and to some extent the average value of complex signals treated by the amplifier. Therefore, when measuring the peak or average value of complex signals with the Spectrometer its phase response should also be taken into account. The reader is further referred to the Appendix, page 110.

The two phase response curves shown in the high frequency range (lower part of Fig. 1.15) indicate the lowest and highest typical distortion obtained for all combinations of the METER RANGE and RANGE MULTIPLIER switches.

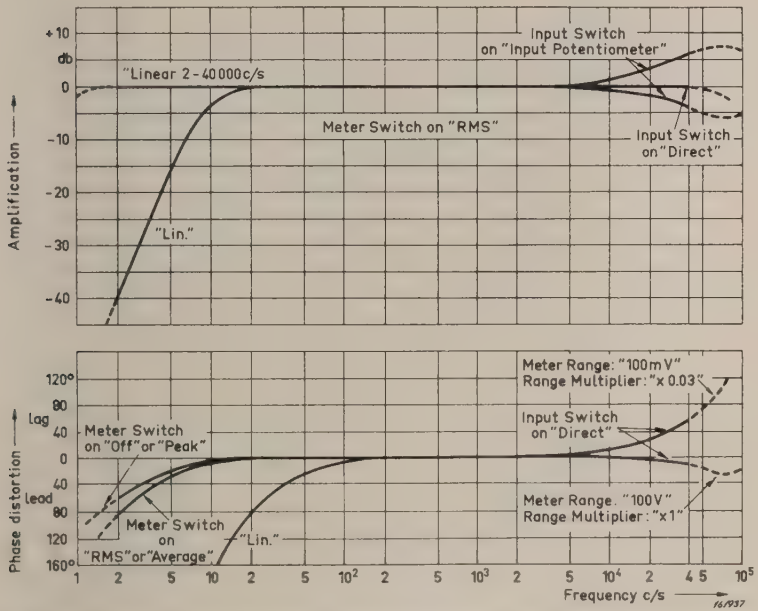

Fig. 1.15. Overall performance of the Spectrometer illustrating amplitude and phase response characteristics.

Signal-to-Noise Ratio. In Fig. 1.16 is illustrated the various noise levels together with the signal levels throughout the Spectrometer set as a linear amplifier. The dot-and-dash line and the dotted line show the noise level for open and for short-circuited AMPLIFIER INPUT respectively. The noise referred to AMPLIFIER INPUT is 15 μV and 5 μV. At the RECORDER output two pairs of dot-and-dash and dotted lines are given. The highest levels will be achieved for full amplification of the output amplifier (RANGE MULTIPLIER on "x 0.01"), whereas the two lowest are derived for minimum amplification (RANGE MULTIPLIER on "x 1").

In the figure is also given the noise levels derived from the separate output amplifier. As illustrated the level is to a certain degree dependent on the setting of the RANGE MULTIPLIER switch. As a final result it can be seen that the signal-to-noise ratio for full scale deflection on the indicating meter

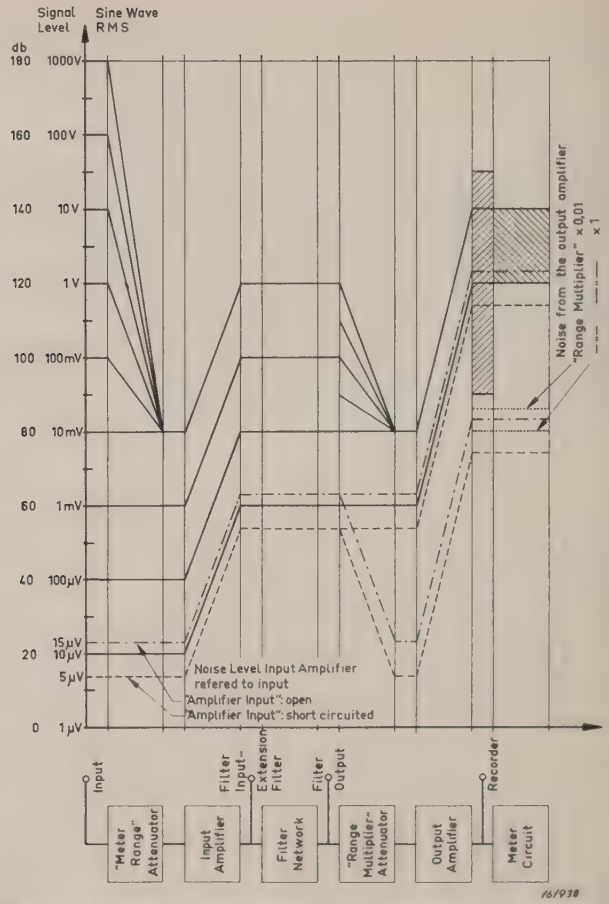

Fig. 1.16. Sketch showing signal levels at different points in the Spectrometer Dotted lines indicate noise levels when used as linear amplifier.

approximately 10 V on RECORDER output, will be better than 60 dB for RANGE MULTIPLIER on "x 1", METER RANGE in any position and AMPLIFIER INPUT short-circuited. Under the same conditions but with AMPLIFIER INPUT open the signal-to-noise ratio will be better than 55 dB. When the Spectrometer handles an output of 32 volt r.m.s. sine wave (45 V peak) a signal-to-noise ratio of 70 dB can be derived.

By using any of the other four positions of the RANGE MULTIPLIER switch,

the signal-to-noise ratio decreases by the same number of dB, corresponding to the increase in amplification. To obtain the best ratio between signal and noise voltage, the RANGE MULTIPLIER switch should thus, during measurements, be set to give as low amplification of the output amplifier as possible, preferably "x 1, 0 dB".

Hum Elimination, Stabilization, Linear Distortion and Microphonic Reduction. The hum level of the instrument is extremely low due to the design and high quality of the amplifying circuits. The level for the Spectrometer as linear amplifier is in total less than 2 μV with reference to the grid of the first tube in the input amplifier. This is achieved by heating the filament of the first tube in each of the two amplifying sections by means of a DC supply, stabilized by zener diodes. This stabilizing effect ensures the stable sensitivity of the amplifier and makes the influence of normal variations in mains voltage practically negligible. Apart from the above, the harmonic distortion produced is for the input amplifier less than one part in a thousand owing to the heavy negative feedback in the amplifier portion. By careful selection of tube types and circuits the effect of microphony is reduced to a minimum, so that even a signal of a few microvolts can be measured.

Overload and Clipping. Care must be taken not to overdrive the input amplifier. By using the Spectrometer in the nonselective condition, overdriving of the amplifier sections can be observed on the indicating meter deflection, i.e. within full deflection there is no overload, provided the signal crest factor is below 4.5. In the selective condition, overdriving of the output amplifier only can be observed on the indicating meter, as signal components outside the pass-band of the filter or weighting network inserted, are attenuated. To obtain an overload indication for the input amplifier a visual indicator is connected in parallel with the output of the input amplifier, as previously described. The indicator lights up when signal peak voltages on this point exceed 4.5 volts (3.16 V r.m.s. sine-wave) i.e. 10 dB higher than the 1 V r.m.s. sine-wave, as stated for 0.1 % nonlinear distortion. The 4.5 volts peak voltage indication limits the measurements to signals with crest factor f_c lower than 4.5, which is also the highest crest factor allowable at full r.m.s. drive.

The higher peaks in the signal have to contain a certain energy to be indicated. When for example measurements are made on noise signals with Gaussian distribution the indicator will only react for noise peaks, which are lower than approximately 2.5 times the r.m.s. value, i.e. f_c lower than 2.5.

To be able to check on how far the input amplifier is driven in making selective measurements, the FUNCTION SELECTOR of the Spectrometer should first be set to position "Linear 2—40000 c/s" and RANGE MULTIPLIER on "0 dB, x 1". The r.m.s. average or peak drive of the amplifier can then be read on the indicating meter. Full deflection corresponds to 1 volt

on the output of the input amplifier. From the above can be seen, that in selective measurements, where the input amplifier is driven to maximum, the sensitivity of the Spectrometer can only be increased by RANGE MULTIPLIER.

Calibration. For calibrating the complete Spectrometer a reference voltage can be connected to the grid of the first tube in the input amplifier. This is readily accomplished by switching METER RANGE to position "Ref". The correct calibration is obtained when the deflection of the indicating meter pointer is adjusted to coincide with the red mark on the meter scale. Any deviation is corrected by one of the sensitivity adjustment potentiometers (described under Output Amplifier, page 25) which are in circuit.

The reference voltage is a square-wave type signal with a repetition frequency equal to that of the power supply. The signal is derived from the power voltage which is clipped and stabilized by a zener diode. Due to the stabilization the signal will vary less than 0.3 % for a 10 % variation in the power supply voltage.

For the reason which follows, the calibration adjustment to the red mark should be carried out with the METER SWITCH in position "R.M.S.", and the FUNCTION SELECTOR switch set to "2—40000 c/s Linear". With the FUNCTION SELECTOR in this position the average reading of the reference signal will also coincide with the red mark on the scale, while the peak value will be indicated by a 0.5—1 dB greater deflection. When the FUNCTION SELECTOR switch is in position "⅓ Octave" and the FILTER SWITCH on "Lin" the R.M.S. calibration will still show a correct value. The average and peak reading, however, will now deviate from this and a deviation of up to 4 dB may be expected when the METER SWITCH is switched to "Peak". The mentioned deviations in reference voltage readings will be smaller when the apparatus is supplied from a power line with a frequency higher than 50 c/s. The reader is also referred to the Appendix, page 110.

Power Supply.

The power supply section contains three rectifiers, one of which supplies the heater current to the apparatus. Another supplies heater current to the tubes of the B & K Cathode Followers or Preamplifiers, via the CONDENSER MICROPHONE input jack, and a third supplies the necessary anode voltages for the amplifiers, as well as the polarization voltage for the Condenser Microphones. The anode voltage and polarization voltage are stabilized by neon tubes.

Polarization Voltage. A socket marked POLARIZATION VOLTAGE on the front panel of the apparatus, makes it possible to quickly measure the polarization voltage for the microphone cartridges. Because of the relatively

high source resistance, a voltmeter with a resistance not less than 20000 Ω/Volt should be used for this measurement. The voltage should be 200 V and can be adjusted around this value by a screwdriver-operated potentiometer on the back of the instrument, refer Fig. 1.17. When used with one of the Condenser Microphones 4131, 4132, 4133 or 4134 the polarization voltage should be 200 Volts. Before the instrument leaves the factory, the voltage is adjusted to this value.

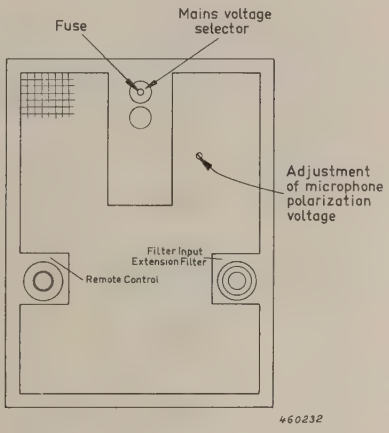

Fig. 1.17. Rear view of Spectrometer.

Fuse and Selection of correct Power Voltage. The primary side of the power transformer is fused, the fuse being placed at the rear of the apparatus, see also Fig. 1.17.

The equipment should be operated from a 50 to 400 Hz (c/s) power line and can be set for mains voltages of 100 — 115 — 127 — 150 — 220 or 240 Volts. The power consumption is approximately 50 Watts. Adjustment for the different supply voltages can be carried out on the rear of the apparatus, refer Fig. 20. If the equipment is to be operated from an accumulator, or from other DC supplies, the use of a converter is necessary.

2. Identification of Control Knobs, Terminals etc.

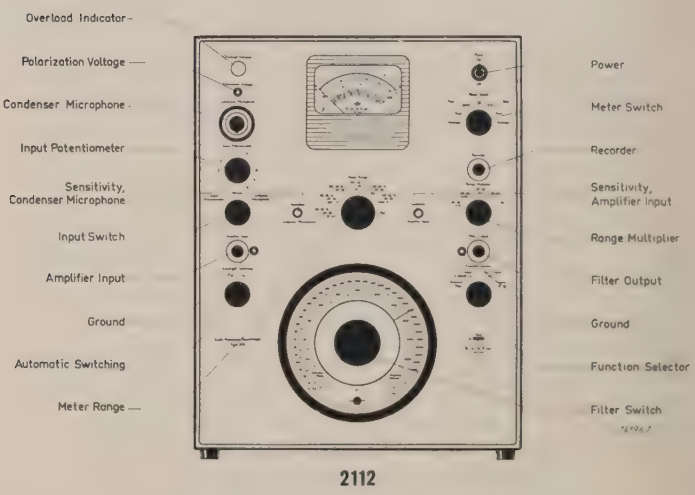

Fig. 2.1. Frontal view of Spectrometer.

Front Plate.

OVERLOAD INDICATOR:	Lamp, giving red light for overdrive of input amplifier section. Indicates for signal peaks exceeding 4.5 V on output of input amplifier.
POLARIZATION VOLTAGE:	For measuring the microphone polarization voltage. A DC voltmeter with an internal resistance of at least 20ooo ohm/volt should be used.
CONDENSER MICROPHONE:	Input terminal for the B & K Condenser Microphones (Cathode Followers) and Preamplifiers.
INPUT POTENTIOMETER:	For continuous variation of input signal attenuation.

SENSITIVITY, CONDENSER MICROPHONE: Screwdriver operated potentiometer, for adjustment of sensitivity, when input "Condenser Microphone" is used.

INPUT SWITCH: Selection of one of the three input facilities
"Input Potentiometer", to be used for relative measurements.
"Direct". The signal is applied direct from the AMPLIFIER INPUT to the attenuator METER RANGE.
"Condenser Microphone".

AMPLIFIER INPUT: The signal is applied to the attenuator METER RANGE either direct or via the INPUT POTENTIOMETER.

GROUND: Connected to the frame of the apparatus.

AUTOMATIC SWITCHING: "On". The connection of the electromechanical drive unit for filter switching, is established with REMOTE CONTROL.
"Off". Connection is broken.

METER RANGE: Step attenuator, 20 dB, for attenuation of input signal.

POWER: For switching the power on and off.

METER SWITCH: For selection of the three different meter indicating properties
"Average"
"Peak" (half peak-to-peak)
"R.M.S."
The three positions ("Fast") to the left gives the smallest damping of the indicating meter deflection. The positions ("Slow") to the right give the highest damping. In the middle position "Off", the meter circuit is disconnected.

RECORDER: Output terminal.

SENSITIVITY, AMPLIFIER INPUT: Screwdriver operated potentiometer for adjustment of sensitivity when terminal AMPLIFIER INPUT is used.

RANGE MULTIPLIER: Step attenuator, 10 dB, for attenuation of the signal level between the filter outputs and output amplifier.

FILTER OUTPUT: Connection to the input of the output amplifier via the attenuator RANGE MULTIPLIER when FUNCTION SELECTOR is in position "External Filter".

GROUND: Connection to frame of apparatus.

FUNCTION SELECTOR: Selection of the various functions.

"External Filter". An external filter set, connected to the terminals FILTER INPUT-EXTENSION FILTERS (on the rar of the apparatus) and FILTER OUTPUT, is inserted between the two amplifier sections.

"Linear, 2—40ooo c/s". The equipment is set up as a linear vacuum-tube voltmeter.

"⅓ Octave, 0 dB". The ⅓ Octave Filters and the Weighting Networks, plus possible ⅓ octave extension filters, can be selected by the FILTER SWITCH.

"Octave, 10 dB". The Octave Filters and the Weighting Networks, plus possible octave extension filter, can be selected by the FILTER SWITCH. An extra attenuation of 10 dB is inserted.

FILTER SWITCH: For selection of the different filters, weighting networks, and possible connected extension filters.

Rear of Equipment.

Refer Fig. 1.17 on page 33.

REMOTE CONTROL: Connections for remote controlling of the Filter Switch.

NOTE: Care has to be taken to ensure proper connection, vide page 23, Remote Control.

FUSE AND MAINS VOLTAGE SELECTOR: Fuse in circuit with primary of mains transformer. Voltage selector, for setting apparatus to various mains voltages.

FILTER INPUT — EXTENSION FILTER: The terminal is divided into two parts: Filter Input and Extension Filter.

"Filter Input". When the special adaptor (trans-

forming the 7-pin jack into a 14 mm coaxial jack) is inserted, connection to the output of the input amplifier is achieved, when FUNCTION SELECTOR is in position "External Filter", "⅓ Octave" or "Octave".

NOTE: A DC voltage of approximately 75 Volts is present. Do not DC load with less than 75 kΩ.

EXTENSION FILTER. The 7-pin jack is connected to the FILTER SWITCH enabling extension filters to be switched in one by one.

NOTE: When extension filters are not connected, the special adaptor should always be inserted in the jack, as this "grounds" all the positions on the FILTER SWITCH intended for extension filters.

ADJUSTMENT
POTENTIOMETER: For microphone polarization voltage.

3. Operation

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3. Operation

GENERAL

Firstly ensure that the instrument is adjusted to the appropriate power supply voltage. If not, remove the fuse on the rear of the Spectrometer, refer Fig. 1.17, and turn the inner part of the combined voltage selector and fuse-holder with a coin or similar means until the white mark points to the desired voltage. After replacing the fuse the apparatus is switched on with the switch marked POWER on the front panel. Immediately, the meter and filter switch scales should light up, and after allowing a warming-up of a few minutes the apparatus is ready for use.

Voltage Measurements.

The apparatus can be used as a linear vacuum tube voltmeter, in the audio frequency range, for absolute and relative measurements of true RMS, average and half the peak-to-peak values. Before actually carrying out the measurements, the sensitivity of the instrument should be calibrated against the built-in reference voltage.

I. Calibration.

1. The control knobs should be set as follows:—

   INPUT SWITCH: "Direct"
   METER RANGE: "Ref."
   METER SWITCH: "Fast", "RMS"
   RANGE MULTIPLIER: "x 1, 0 dB"
   FUNCTION SELECTOR: "Linear, 2—40ooo c/s"
   Control knobs not mentioned may be in any position.

2. The meter should now show a deflection to the red mark on the scale. Possible deviations are corrected by the potentiometer marked SENSITIVITY — AMPLIFIER INPUT on the front panel.

II. Measuring.

1. The voltage to be measured is fed to the AMPLIFIER INPUT terminal, and the INPUT SWITCH is kept in position "Direct" if absolute measurements are desired, or set to position "Input Potentiometer" if relative measurements are to be made (in the latter case refer also Description, Input Circuit, page 14.
2. The METER SWITCH is set according to the desired type of rectifica-

tion, i.e. "Average", "Peak" or "RMS". If frequencies below 20 Hz (c/s) are to be measured, one of the positions "Slow" should be used.

3. The FUNCTION SELECTOR is kept in position "Linear", and the desired voltage range chosen by means of the METER RANGE and RANGE MULTIPLIER switches. If possible, the RANGE MULTIPLIER switch should be kept in position "× 1 (0 dB)", the reason for this being given under Description, Signal-to-Noise Ratio, page 29.

III. Reading on Indicating Meter.

(Input switch in position "Direct").

Volts. The input signal voltage, which gives full deflection on the meter, is found by multiplying the number of mV or V indicated on the chosen position of the METER RANGE switch by the factor indicated on the position of the RANGE MULTIPLIER switch. If, for example:—

METER RANGE switch is in position "1 V, —20 dB"

RANGE MULTIPLIER switch is in position "× 1, 0 dB"

Full deflection on the meter occurs for 1 Volt × 1 = 1 Volt.

By using the full amplification of the apparatus, full deflection on the meter corresponds to an input signal voltage of 10 mV × 0.01 = 100 μV.

dB re. 1 Volt. The voltage level in dB, relative to 1 V, indicated on the meter will be found by adding the dB-values indicated by the position of the METER RANGE and RANGE MULTIPLIER switches to the number of dB indicated on the instrument meter An example will illustrate this:—

METER RANGE in position "—60 dB"

RANGE MULTIPLIER in position "—10 dB"

Deflection on the meter: + 20 dB.

— 60 dB — 10 dB + 20 dB = — 50 dB re. 1 V = 3.16 mV

IV. Recording.

The voltage measured may be recorded on the B & K Level Recorder, Type 2305, this being connected to the output socket marked RECORDER.

The adjustments necessary are made as described in Automatic Recording of Voltage Analysis, paragraph A, item I and II, page 42.

Adjustment to the signal is made as outlined in item II, 3 above.

For reading of absolute values on the recording paper paragraph C page 47 under Automatic Recording of Voltage Analysis is utilized. This paragraph is intended for the reading of spectrograms but can be used direct for the reading of linear measurements, providing it is remembered that for FUNCTION SELECTOR in position "Linear, 2—40000 c/s" "0 dB" should also be read, similar to position "⅓ Octave".

Audio Frequency Voltages Analysis with $^1/_3$ Octave or Full Octave Filters.

When complex voltages are analysed, care should be taken not to overdrive the amplifiers (see also Output Voltage on page 25 and Overdriving page 31).

I. Calibration.
The instrument is calibrated and a suitable deflection on the meter is obtained as described under "Voltage Measurements" item I and II.

II. Analysing.
Analysing can then be carried out by setting the FILTER SWITCH to the desired filter and the FUNCTION SELECTOR to either "⅓ Octave 0 dB" or "Octave, 10 dB". In the latter position 10 dB should be added to the meter deflection (see the Description, Design, on page 19).
When low-level components of a frequency spectrum are to be measured, the amplification of the instrument should only be increased by the RANGE MULTIPLIER switch, otherwise the input amplifier will be overdriven.

III. Reading on Indicating Meter.
Vide under "Voltage Measurements", item III.
NOTE: In the case of 1/1 octave analysis the measuring result should be multiplied by 3.16 or alternatively 10 dB should be added.

IV. Remote Control.
The filter switching can be remotely controlled when connections to the REMOTE CONTROL socket are made as illustrated in Fig. 1.12 on page 24.

Automatic Recording of Voltage Analysis.

If the Spectrometer is connected to the B & K Level Recorder Type 2305, the analysis of complex signals can be recorded automatically and will then be available in the form of a spectrogram. By using preprinted, frequency calibrated recording paper on the Level Recorder, the spectrogram will appear as a calibrated amplitude vs. frequency diagram of the measured signal .For this operation the paper drive of the Level Recorder must be synchronized with the filter switching of the Spectrometer.

MEASURING ARRANGEMENT
Connect the instruments as shown in Fig. 3.1.

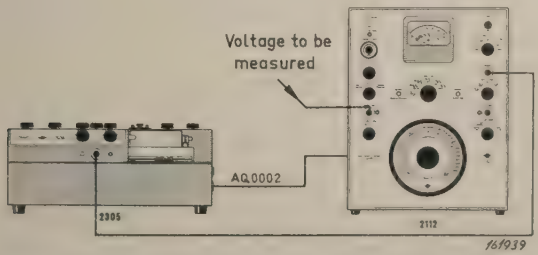


Fig. 3.1. Measuring arrangement for automatic recording of voltage analyses

The REMOTE CONTROL socket on the back of the Spectrometer should be connected to the seven-pin REMOTE CONTROL socket on the Level Recorder, by the cable AQ 0002.
Then proceed as follows:—

A. RECORDING OF SINGLE SPECTROGRAMS

I. Calibration of the Spectrometer.

1. The control knobs should be set as follows:—
   INPUT SWITCH: "Direct"
   METER RANGE: "Ref."
   METER SWITCH: "Fast", "RMS"
   RANGE MULTIPLIER: "× 1, 0 dB"
   FUNCTION SELECTOR: "Linear, 2—40ooo c/s"
   Control knobs not mentioned may be in any position.
2. The meter should now show a deflection to the red mark on the scale. Possible deviations being corrected by the screwdriver operated potentiometer marked SENSITIVITY — AMPLIFIER INPUT on the front panel.

II. Calibration of the Level Recorder.

1. Potentiometer 50 dB employed. For potentiometers with other ranges refer paragraph B, page 46.
2. Set control knobs as follows:—
   POTENTIOMETER RANGE to "50"
   RECTIFIER RESPONSE to "R.M.S."
   LOWER LIMITING FREQUENCY to "20"
   WRITING SPEED: 50 mm paper: 500 mm/sec, large figures.*)
   100 mm paper: 1ooo mm/sec, small figures.*)
   PAPER DRIVE to "Stop" and "Forward".
   SINGLE CHART-CONT. RECORD. in its upper position
   POWER to "On"
   Allow a few minutes for warming up, then switch
   MOTOR to "On"
   INPUT ATTENUATOR to "10"
3. By means of the INPUT POTENTIOMETER the deflection of the stylus is adjusted to full deflection minus 4 dB. (Using 50 dB Range Potentiometer, 50 — 4 = 46 dB).

III. Adjustment of the Single Chart automatic stop:—

1. Insert the desired type of frequency calibrated paper. If necessary, see the instruction manual for Level Recorder Type 2305.

---

*) With this combination of "Lower Limiting Frequency" and "Writing Speed" setting, the Level Recorder is operating in an abnormal condition and therefore tends to overswing as visible on the recording in Fig. 3.3. The abnormal condition is used only during synchronization to give an unambiguous indication of the filter switching point.

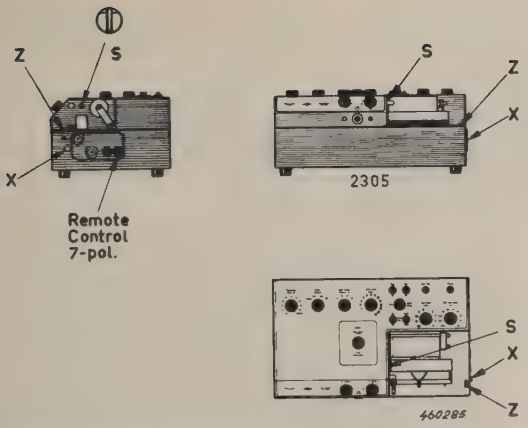


Fig. 3.2. Level Recorder with indication of: Synchronizing Gear Lever X, Screw S and Finger Wheel Z.

2. Pull the Gear Lever (ratio 1 : 10) to its outer position. The Lever is marked X in Fig. 3.2.
3. Set the "Paper Speed" to 10 mm/sec, small figures.
4. The toggle switch PAPER DRIVE is set to "Start", whereby the paper starts moving. If not, press the pushbutton SINGLE CHART-CONT. RECORD. After one chart length or less the paper automatically stops.
5. Move the recording paper by means of the finger wheel Z shown in Fig. 3.2 until the writing stylus points at the "10" Hz (c/s) line.

IV. Synchronization between Level Recorder and Spectrometer.

The switching of the Filter Switch on the Spectrometer can now be synchronized with the paper movement.

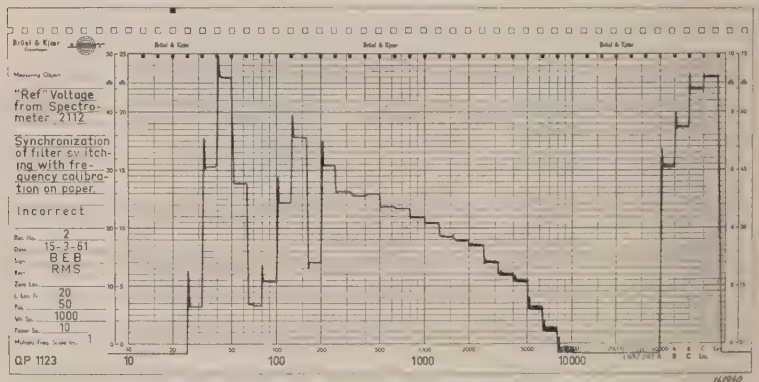
1. Turn the screw S shown in Fig. 3.2 until the marking cut in the screw is in its upper position.
2. When proceeding from above the following control knobs on the Spectrometer have to be set to:

   FUNCTION SELECTOR "⅓ Octave — 0 dB"
   AUTOMATIC SWITCHING "Off"
   FILTER SWITCH to one step before (counter-clockwise) the position "12.5"
   AUTOMATIC SWITCHING "On"
3. The control knobs on the Level Recorder have to be moved as follows:

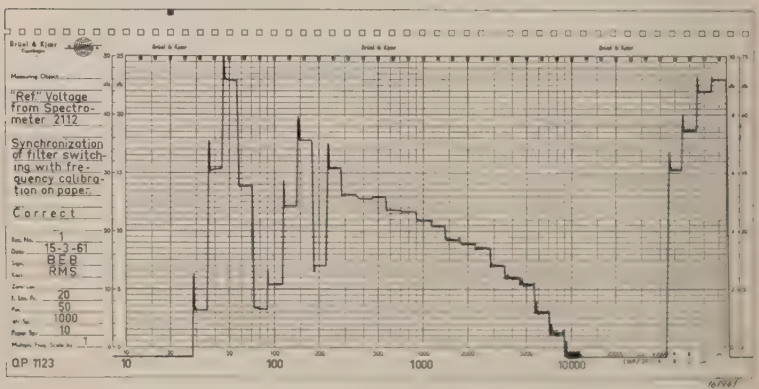
   Set PAPER DRIVE to "Stop".

Press the pushbutton marked "Single Chart-Cont. Record".
The paper starts moving, and then the reference voltage commences to be recorded.
The pushbutton should be released when the paper has moved to about the "200" — "300" Hz (c/s) line.

4. Correct synchronization is obtained when the switching over from the "80" Hz (c/s) to the "100" Hz (c/s) filter takes place on the line "90" Hz (c/s), refer Fig. 3.3a and b.



(a)



(b)

Fig. 3.3. Synchronization between recording paper and filter switching.
(a) Incorrect.
(b) Correct.
(Concerning the overswing on the recording, refer to the footnote on page 42).

To ensure that synchronization is achieved within the proper ⅓ octave filter the component of the power supply fundamental frequency should be represented as the highest value on the spectrogram within the filter covering this fundamental. From Fig. 3.3 b it is seen that the fundamental (herein 50 Hz (c/s)) is the highest value and rests within the filter concerned. In the case of a 60 Hz (c/s) power supply frequency the highest value would be contained within the 63 Hz (c/s) filter.

5. If the synchronization is incorrect, the paper should be shifted by the finger wheel Z.

   NOTE: To avoid the effect of play between the gear wheels, the paper should always be shifted in a manner, so that it approaches the correct point in the reverse direction. If, for example, it has to be shifted corresponding to a higher frequency, i.e. forward direction, the paper is shifted a little beyond, and finally reversed to the desired point.

   To be able to see how far the paper has to be shifted, it is recommended to draw a line by means of the stylus, when the paper has stopped. By using this line, the paper is now shifted the required distance to give correct synchronization, this being easily seen from the previous recording. To draw the line, the stylus is given a deflection which may be obtained by pressing the knob "100 mV. Ref.". Should the paper have to be shifted equal to a lower frequency the respective distance may be marked on the paper beforehand.
6. To check the synchronization, run the recording to about the "2000" — "3000" Hz (c/s) line. When synchronized correctly the switching from the "800" Hz (c/s) to the "1000" Hz (c/s) filter should now take place at the "900" Hz (c/s) line. If this is not the case, run the paper to the following charted portion and repeat from item IV. 3.
7. PAPER DRIVE is set to "Start", whereby the paper moves to the pre-selected single chart stop.

V. Adjustment to the Signal.

1. The control knobs RECTIFIER RESPONSE, LOWER LIMITING FREQUENCY, WRITING SPEED and PAPER SPEED on the Level Recorder are set to positions, whichever are desired for the measurement in question.

   NOTE: By choosing the positions of LOWER LIMITING FREQUENCY and WRITING SPEED the stability and overswing of the Recorder should be taken into account. For more details, refer to the manual for the Level Recorder Type 2305.
2. The voltage to be measured is applied to the AMPLIFIER INPUT on the Spectrometer. Keeping control knobs in positions as outlined above, change the following on the Spectrometer to:—

   FUNCTION SELECTOR: "Linear, 2—40000 c/s"

METER RANGE and RANGE MULTIPLIER:	Are set so that a suitable deflection of the writing stylus is obtained (40—45 dB for 50 dB Range Potentiometer employed). The RANGE MULTIPLIER should be in a position as near "× 1, 0 dB" as possible. The reason being given in the Description, Signal-to-Noise Ratio, page 29.
METER SWITCH:	"Off" (recommended at low frequencies and/or high amplitudes).

VI. Recording.

On proceeding from "Adjustment to the Signal" the recording can be started when:

1. The FUNCTION SELECTOR is set to "⅓ Octave, 0 dB" or "Octave, 10 dB", whichever is desired for the measurement.
   NOTE: In octave analysis it is recommended to compensate for the 10 dB extra attenuation by increasing the amplification of the ouput amplifier the same amount, the RANGE MULTIPLIER is thus turned one step counter-clockwise. By doing so the dynamic range of the Spectrometer is fully utilized.
2. The pushbutton SINGLE CHART - CONT. RECORD. is operated, allowing the recording to start.
3. It is recommended, additionally, to write down on the recording paper the positions of the METER RANGE, RANGE MULTIPLIER and FUNCTION SELECTOR controls.

B. EMPLOYMENT OF DIFFERENT POTENTIOMETERS

When using other than a 50 dB Potentiometer during measurement, the following should be taken into account:—

I. Items A II through A IV are firstly carried out with a 50 dB Range Potentiometer for synchronization.

II. Apply the desired Range Potentiometer and calibrate the deflection of the Level Recorder stylus as follows:—
   1. FUNCTION SELECTOR on Spectrometer to "Linear, 2—40000 c/s".
   2. POTENTIOMETER RANGE to the Potentiometer employed.*)
   3. WRITING SPEED on:—
      160 mm/sec for 50 mm paper (large figures)
      315 mm/sec for 100 mm paper (small figures)
   4. PAPER DRIVE to "Start" and "Forward".

*) By employing a linear Range Potentiometer 10—35 mV or 10—110 mV (ZR 0001 or ZR 0002 respectively) the resolving power of the recording system of the Level Recorder is not the same at minimum deflection as it is at maximum. Therefore a particular position of "Potentiometer Range" will not be optimum for all degrees of deflection.
It is recommended to set "Potentiometer Range" to "12" when using a 10—35 mV Potentiometer and "16" when a 10—110 mV Potentiometer and further to combine "Writing Speed" and "Lower Limiting Frequency" setting so that unstability and overshoot of the recording system is avoided in the range of deflection wanted.

5. INPUT ATTENUATOR is set to:—

Range Potentiometer	"Input Attenuator"
10 dB	"30"
25 dB	"30"
75 dB	"0"
10— 35 mV	"50"
10—110 mV	"40"

6. With the Level Recorder INPUT POTENTIOMETER the deflection of the stylus is adjusted to:—

Range Potentiometer		Deflection of Stylus
10		10-4 = 6 dB
25		25-4 = 21 dB
75		75-19 = 56 dB
	50 mm	*100 mm paper*
10— 35 mV	20 mm	40 mm deflection on stylus scale
10—110 mV	26.5 mm	53 mm deflection on stylus scale

Then continue with item A V through A VI.

C. READING OF ABSOLUTE VALUES FROM THE SPECTROGRAM

I. When the equipment is calibrated as outlined in paragraph A, item II, 3 or B, item II, 6 the reading from the spectrogram can be taken as given below:

1. **Logarithmic Range Potentiometer 10, 25 and 50 dB employed.**
The absolute value of the signal applied to the "Amplifier Input" of the Spectrometer is read in dB re. 10 V as:—

The value in dB on the spectrogram + the sum of numbers of dB indicated by METER RANGE, RANGE MULTIPLIER and FUNCTION SELECTOR — dB range of Potentiometer employed (10, 25 or 50 dB), re. 10 V.

Example:
50 dB Potentiometer
Deflection of the stylus: 46 dB
METER RANGE: "+ 20 dB"
RANGE MULTIPLIER: " — 10 dB"
FUNCTION SELECTOR: ⅓ Octave, 0 dB"
46 dB + 20 dB — 10 dB + 0 dB — 50 dB = + 6 dB, re. 10 V = 20 V

Example:
25 dB Potentiometer
Deflection of the stylus: 13 dB
METER RANGE: "40 dB"
RANGE MULTIPLIER: "0 dB"
FUNCTION SELECTOR: "Octave, 10 dB"
13 dB — 40 dB + 0 dB + 10 dB — 25 dB = — 42 dB, re. 10 V = 80 mV.

2. **Logarithmic Range Potentiometer 75 dB employed.**
The absolute value read in dB re. 10 V is:—

The value in dB on the spectrogram + the sum of numbers of dB indicated by METER RANGE, RANGE MULTIPLIER and FUNCTION SELECTOR — 60 dB, re. 10 V.

NOTE: To avoid overdriving of the output amplifier in the Spectrometer, the output voltage should not exceed 45 V peak. When for instance recording a sine wave in position R.M.S. the deflection of the stylus should not exceed 70 dB.

Example:

75 dB Potentiometer
Deflection of the stylus: 60 dB
METER RANGE: "0 dB"
RANGE MULTIPLIER: "— 10 dB"
FUNCTION SELECTOR: "1/3 Octave, 0 dB"
60 dB + 0 dB — 10 dB + 0 dB — 60 dB = — 10 dB, re. 10 V = 3.16 V

3. Linear Range Potentiometer 10—35 mV and 10—110 mV.

The absolute value can be read as follows:

First, a value z is introduced, which is derived from:—

z = mV or Volt indicated by position of METER RANGE × factor indicated by RANGE MULTIPLIER × factor indicated by FUNCTION SELECTOR.

NOTE: RANGE MULTIPLIER in position "o.3" or "o.03", factor equals o.316 or o.0316 respectively
FUNCTION SELECTOR in position "1/3 Octave, 0 dB" factor equals 1
FUNCTION SELECTOR in position "Octave, 10 dB" factor equals 3.16

Second, by using this value z the reading on the spectrogram is derived by the aid of the following table, in which can be read the voltages that give zero deflection and full deflection respectively, together with how much 10 mm and 20 mm interval on the paper equal in mV or volt:—

Level Recorder Stylus Deflection (Stylus Scale)	Linear Range Potentiometer 10—35 mV		10—110 mV		
	Paper Width 50 mm	100 mm	50 mm	100 mm	
Zero	$\frac{z}{3.16}$	$\frac{z}{3.16}$	$\frac{z}{10}$	$\frac{z}{10}$	mV or V
Full	$\frac{z}{3.16} \times 3.5$	$\frac{z}{3.16} \times 3.5$	$\frac{z}{10} \times 11$	$\frac{z}{10} \times 11$	mV or V
10 mm interval	$\frac{z}{3.16} \times 0.5$		$\frac{z}{10} \times 2$		mV or V
20 mm interval		$\frac{z}{3.16} \times 0.5$		$\frac{z}{10} \times 2$	mV or V

NOTE: From the table it will be seen that z should be chosen so that it contains figures 316 or 1 for 10—35 mV and 10—110 mV Range Potentiometer respectively to give a simple figure in mV or volt.

Example: 10—35 mV Range Potentiometer.

METER RANGE "10 mV"
RANGE MULTIPLIER "0.3"
FUNCTION SELECTOR "1/3 Octave, 0 dB"

$z = 10\ mV \times 0.316 \times 1 = 3.16\ mV.$

Zero deflection $= \frac{3.16}{3.16} = 1$ mV for 50 and 100 mm width paper.

Full deflection $= \frac{3.16}{3.16} \times 3.5 = 3.5$ mV for 50 and 100 mm width paper.

10 mm on 50 mm paper and 20 mm on 100 mm paper $\left.\right\} \frac{3.16}{3.16} \times 0.5 = 0.5$ mV.

Example: 10—110 mV Range Potentiometer.

METER RANGE "1 V"
RANGE MULTIPLIER "0.03"
FUNCTION SELECTOR "Octave, 10 dB"

$z = 1\ Volt \times 0.0316 \times 3.16 = 0.1\ Volt.$

Zero deflection $= \frac{0.1}{10} = 0.01$ Volt for 50 and 100 mm width paper

Full deflection $= \frac{0.1}{10} \times 11 = 0.11$ Volt for 50 and 100 mm width paper

10 mm on 50 mm paper and 20 mm on 100 mm paper $\left.\right\} \frac{0.1}{10} \times 2 = 0.02$ Volt.

II. Setting of Spectrometer for zero or full stylus deflection reference reading.

If it is required to record voltages in dB above or below a certain reference value, the voltage equal to 0 dB deflection or full deflection respectively of the stylus is found by means of the tables given below. The equipment has to be calibrated as outlined in paragraph A item II, 3 or B item II, 6.

Voltage on "Amplifier Input" of Spectrometer Referred to zero Deflection on Recording Paper	The Sum of dB Indicated by "Meter Range", "Range Multiplier" and "Function Selector".			
	Logarithmic Range Potentiometer			
	10 dB	25 dB	50 dB	75 dB
10 μV		Cannot be adjusted for the μV, mV or V given.	—70 dB	—60 dB
31.6 -	—100 dB		—60 -	—50 -
100 -	—90 -		—50 -	—40 -
316 -	—80 -		—40 -	—30 -
1 mV	—70 -		—30 -	—20 -
3.16 -	—60 -		—20 -	—10 -
10 -	—50 -		—10 -	0 -
31.6 -	—40 -		0 -	+10 -
100 -	—30 -		+10 -	+20 -
316 -	—20 -		+20 -	+30 -
1 V	—10 -		+30 -	+40 -
3.16 -	0 -		+40 -	
10 -	+10 -			
31.6 -	+20 -			
100 -	+30 -			

Voltage on "Amplifier Input" of Spectrometer Referred to full Deflection on Recording Paper.	The Sum of dB Indicated by "Meter Range", "Range Multiplier" and "Function Selector".
	Logarithmic Range Potentiometer 10, 25 and 50 dB
100 μV	—100 dB
316 -	—90 -
1 mV	—80 -
3.16 -	—70 -
10 -	—60 -
31.6 -	—50 -
100 -	—40 -
316 -	—30 -
1 V	—20 -
3.16 -	—10 -
10 -	0 -
31.6 -	+10 -
100 -	+20 -
316 -	+30 -
1000 -	+40 -

75 dB Range Potentiometer: Full deflection cannot be obtained when utilizing the calibration stated beforehand.

Automatic Recording of Sound Spectrograms.

One of the most important features of the combined Spectrometer, B & K Condenser Microphone and Level Recorder is the ability to record sound spectrograms automatically. Some typical examples of this type of measurement are given under "Application". The calibration, synchronization and measuring procedures are as follows:

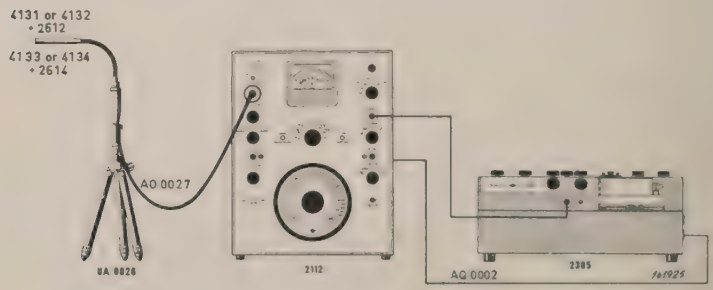


Fig. 3.4. Measuring arrangement for automatic recording of sound spectrograms.

MEASURING ARRANGEMENT

Connect the Spectrometer and Level Recorder as shown in Fig. 3.4.
The REMOTE CONTROL socket on the rear of the Spectrometer should be connected to the seven-pin REMOTE CONTROL socket of the Level Recorder by using the cable AQ 0002.

A. RECORDING OF SINGLE SPECTROGRAMS

I. Set up and Calibration.

The procedure outlined in "Automatic Recording of Voltage Analysis", paragraph A, "Recording of Single Spectrograms", should be followed from item I to IV (incl.).

NOTE: In most cases whenever sound measurements are carried out, a 50 dB Range Potentiometer will be suitable. However, in some cases it might be advantageous to utilize potentiometers with another range. The procedure laid down in the above mentioned chapter paragraph B on page 46 can, in such circumstances be followed.

II. Calibration according to the selected Microphone.

The measuring arrangement has now to be calibrated to the Microphone employed. This can be done by:—

Microphone 4131 or 4132 employed.
Employment of the reference voltage in the Spectrometer and the correction factor "K" valid for the respective Microphone. (Information on "K" is given in Fig. 3.5).

Microphone 4133 or 4134 employed.
1. Check the microphone polarization voltage. Further instructions concerning this is given in the Description of the Power Supply, page 32.

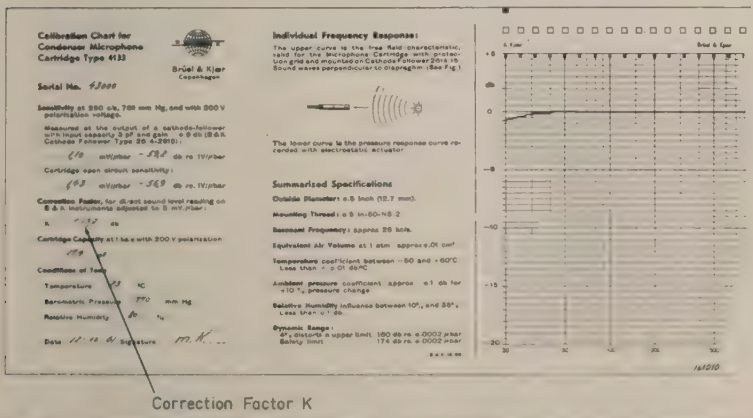


Fig. 3.5. Typical microphone calibration chart with indication of the correction factor K.

Microphone 4131 or 4132 employed.

1. Check the microphone polarization voltage. Further instructions concerning this are given in the Description of the Power Supply, page 32.
2. Mount the Condenser Microphone as shown in Fig. 3.4. Allow a few minutes to warm up.
3. The control knobs of the Spectrometer should be operated as follows:—
   INPUT SWITCH to "Condenser Microphone"
   FUNCTION SELECTOR to "Linear, 2—40000 c/s"
   The other control knobs are kept as described above.
4. The deflection on the indicating meter should now be adjusted to the red mark plus the correction factor "K" of the Microphone. This being done by means of the potentiometer SENSITIVITY, CONDENSER MICROPHONE accessible on the front.

▼

Example 1.
"K" = 1.5 dB
The pointer has to be adjusted to 16 dB + 1.5 dB = 17.5 dB
16 dB corresponds to the red mark.

Example 2.
"K" = — 0.3 dB
The pointer has to be adjusted to 16 dB — 0.3 dB = 15.7 dB

▼

Microphone 4133 or 4134 employed.

2. Mount the Condenser Microphone as shown in Fig. 3.4. Allow a few minutes to warm up.
3. The control knobs of the Spectrometer should be operated as follows:—
   INPUT SWITCH to "Condenser Microphone"
   FUNCTION SELECTOR to "Linear, 2—40000 c/s"
   The other control knobs being kept as described above.
4. Adjust the deflection of the indicating meter pointer to the red mark on the scale by turning the screwdriver-operated potentiometer SENSITIVITY, CONDENSER MICROPHONE.
5. Increase the sensitivity of the Level Recorder by means of the INPUT POTENTIOMETER, and, if necessary, by the INPUT ATTENUATOR to:—
   the correction factor "K" dB — 10 dB,
   where "K" is the correction factor of the Microphone. (Information concerning this factor can be found in Fig. 3.5).

Example 1.
"K" = 13.3 dB
The sensitivity of the Level Recorder should be increased by:—
13.3 dB — 10 dB = 3.3 dB

Example 2.
(50 dB Range Potentiometer).
"K" = 16 dB
The sensitivity of the Level Recorder should be increased by:—
16 dB — 10 dB = 6 dB
The stylus should then actually rest at 46 dB + 6 dB = 52 dB.
This is of course not possible as the full deflection is equal to 50 dB. A way of increasing the sensitivity could be:—

Microphone 4133 or 4134 employed.
(a) Decrease sensitivity by INPUT POTENTIOMETER on Level Recorder
10 dB — 6 dB = 4 dB
(b) Increase sensitivity 10 dB by INPUT ATTENUATOR
The total increase is then
—4 dB + 10 dB = 6 dB.

The measuring arrangement has now been calibrated so that an absolute reading of the S.P.L. value present on the microphone diaphragm, can be carried out on the spectrogram. Further information is given in a following paragraph "Reading of Absolute Value of the Spectrogram". For absolute reading of the indicating meter deflection, reference is made to "Spectrometer set up as Precision Sound Level Meter", page 57.

III. Adjustment to the Signal.

The Microphone is exposed to the sound to be analysed.

1. The control knobs RECTIFIER RESPONSE, LOWER LIMITING FREQUENCY, WRITING SPEED and PAPER SPEED on the Level Recorder are set to positions, whichever are desired for the measurements.

   NOTE: When choosing the positions of LOWER LIMITING FREQUENCY and WRITING SPEED the stability and overswing of the Recorder should be taken into account. For more details, refer to the manual for the Level Recorder Type 2305.

2. Keeping other control knobs in positions as outlined above, the following knobs on the Spectrometer have to be set to:—

METER RANGE and RANGE MULTIPLIER:	Are set so that a suitable deflection of the writing stylus is obtained. (40—45 dB for 50 dB Range Potentiometer employed). The RANGE MULTIPLIER should be in a position as near "× 1, 0 dB" as possible, the reason being given in the Description Signal-to-Noise Ratio page 29.
METER SWITCH:	"Off" (recommended at low frequencies and/or high amplitudes).

IV. Recording.

On proceeding from "Adjustment to the Signal" the recording can be started when:—

1. The FUNCTION SELECTOR is set to "⅓ Octave, 0 dB" or "Octave, 10 dB", whichever is desired for the measurement.
2. The pushbutton SINGLE CHART — CONT. RECORD. is operated, allowing the recording to start.
3. Additionally, it is recommended to write down on the recording

paper the positions of METER RANGE, RANGE MULTIPLIER and FUNCTION SELECTOR controls.

B. EVALUATION OF SOUND SPECTROGRAMS

Sound Pressure Level (S.P.L.) value is indicated when the Filter Switch on the Spectrometer is in position "Lin.", see Fig. 3.6a and b.

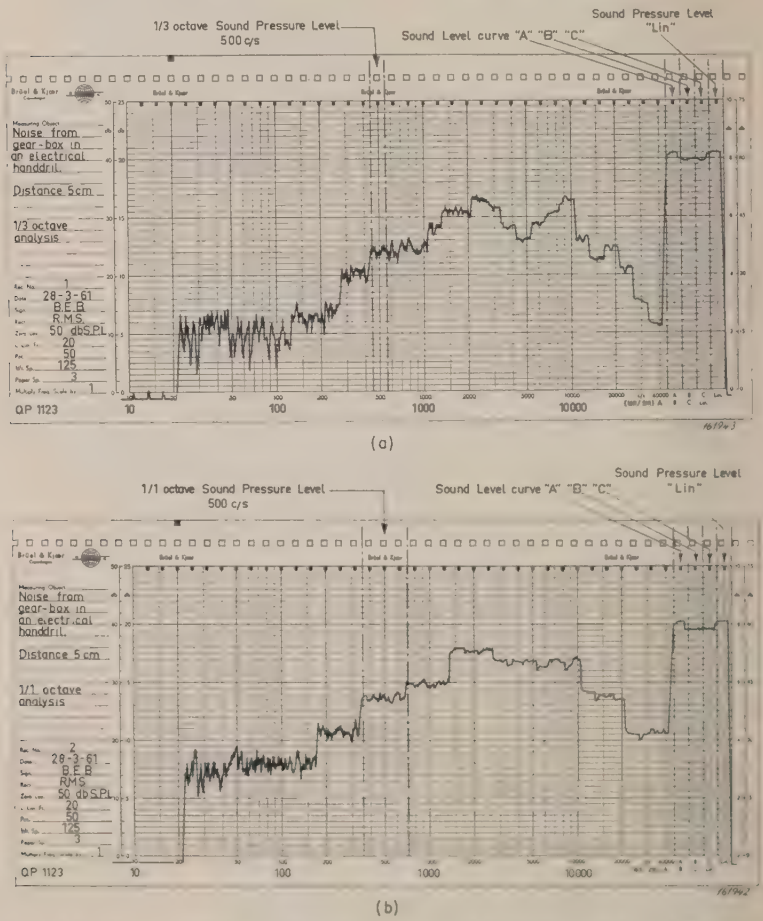


Fig. 3.6. Example of recorded spectrograms with indication of Sound Pressure Level and Sound Level.
(a) ⅓ octave analysis.
(b) 1/1 octave analysis.

When the Spectrometer is switched to analyse with ⅓ Octave Filters, the Sound Pressure Level within ⅓ octave is measured only, and is indicated when the Spectrometer Filter Switch is in any of the positions from "25" to "40000". See Fig. 3.6a. When the Spectrometer is used with Extension Filter Set Type 1620, or ZS 0146, the ⅓ Octave S.P.L. value is obtained, when the filter switch is in any of the positions "12.5" to "40000".
When switching the Spectrometer to Octave Filters, the Sound Pressure Level with a bandwidth of 1 octave only is measured. See Fig. 3.6b.

Sound Level is measured when the FILTER SWITCH on the Spectrometer is in one of the positions "A", "B" or "C" and the FUNCTION SELECTOR in "⅓ Octave, 0 dB" or "Octave, 10 dB". See also Fig. 3.6a and b.
When the measuring arrangement is calibrated as described in the previous paragraphs the above mentioned levels can all be found from the recorded spectrogram, see the following paragraph.

C. READING OF ABSOLUTE VALUES FROM THE SPECTROGRAM

When the calibration procedure is carried out as described above in items A I and II the absolute value in S.P.L. or S.L. re. 2×10^{-4} μbar on the diaphragm of the Microphone can be read on the spectrogram by following the procedure given below.

Microphone 4131 or 4132 employed.

1. 50 dB Range Potentiometer applied:—
   The value in dB on the spectrogram
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   — 30 dB

Example 1.
Deflection of the stylus: 46 dB
Position of METER RANGE: "60 dB S.L."
Position of RANGE MULTIPLIER: "0 dB × 1"
Position of FUNCTION SELECTOR: "⅓ Octave, 0 dB"
46 dB + 60 dB + 0 dB + 0 dB — 30 dB = 76 dB
S.P.L. or S.L.

Microphone 4133 or 4134 employed.

1. 50 dB Range Potentiometer applied:—
   The value in dB on the spectrogram
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   — 20 dB

Example 1.
Deflection of the stylus: 46 dB
Position of METER RANGE: "60 dB S.L."
Position of RANGE MULTIPLIER: "0 dB × 1"
Position of FUNCTION SELECTOR: "⅓ Octave, 0 dB"
46 dB + 60 dB + 0 dB + 0 dB — 20 dB = 86 dB
S.P.L. or S.L.

Microphone 4131 or 4132 employed.

Example 2.

Deflection of the stylus: 10 dB
Position of METER RANGE: "80 dB S.L."
Position of RANGE MULTIPLIER: "— 10 dB × o.3"
Position of FUNCTION SELECTOR: "Octave, 10 dB"
10 dB + 80 dB — 10 dB + 10 dB — 30 dB = 60 dB S.P.L. or S.L.

2. 10 dB Range Potentiometer applied:—
   The value in dB on the spectrogram
   + the number in dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   + 10 dB
3. 25 dB Range Potentiometer applied:—
   The value in dB on the spectrogram
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   — 5 dB
4. 75 dB Range Potentiometer applied:—
   The value in dB on the spectrogram
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   — 40 dB

Microphone 4133 or 4134 employed.

Example 2.

Deflection of the stylus: 10 dB
Position of METER RANGE: "80 dB S.L."
Position of RANGE MULTIPLIER: "— 10 dB × o.3"
Position of FUNCTION SELECTOR: "Octave, 10 dB"
10 dB + 80 dB — 10 dB + 10 dB — 20 dB = 70 dB S.P.L. or S.L.

2. 10 dB Range Potentiometer applied:—
   The value in dB on the spectrogram
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   + 20 dB
3. 25 dB Range Potentiometer applied:—
   The value in dB on the spectrogram
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   + 5 dB
4. 75 dB Range Potentiometer applied:—
   The value in dB on the spectrogram
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   — 30 dB

NOTE: For 75 dB Range Potentiometers the calibration is different from that which is valid for the three other Range Potentiometers, refer "Automatic Recording of Voltage Analysis", paragraph B on page 46, which is also used for sound spectrogram recordings.
Due to the risk of overdriving, the voltage from the output amplifier in the Spectrometer should not exceed 45 V peak.

Derivation of above formulae.
The calculation of the formulas used by the different Range Potentiometers, item 1, 2, 3, and 4 above, can be seen from the general formula:—

Microphone 4131 or 4132.

The value in dB on the spectrogram
+ the number of dB S.L. indicated by METER RANGE
+ the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
— dB deflection stated for calibration of the Level Recorder*)
— 4 dB + 20 dB

Example:
75 db Range Potentiometer.
The value in db on the spectrogram
+ the number of db S.L. indicated by METER RANGE
+ the sum of numbers of db indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
— 56 db — 4 db + 20 db

The last line in the formula being — 40 dB, refer item 4 above.

Microphone 4133 or 4134.

The value in dB on the spectrogram
+ the number of dB S.L. indicated by METER RANGE
+ the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
— dB deflection stated for calibration of the Level Recorder*)
— 4 dB + 20 dB + 10 dB

Example:
50 dB Range Potentiometer.
The value in dB on the spectrogram
+ the number of dB S.L. indicated by METER RANGE
+ the sum of numbers of dB incated by RANGE MULTIPLIER and FUNCTION SELECTOR
— 46 dB — 4 dB + 20 dB + 10 dB

The last line in the formula being — 20 dB, refer item 1 above.

Spectrometer Set up as Precision Sound Level Meter.

In several cases it is desired to measure the Sound Pressure Level or the Sound Level by means of the Spectrometer, giving a direct reading. When measuring the Sound Level the characteristic of the complete set-up is in accordance with the I.E.C. standards for Precision Sound Level Meters, presuming that the Spectrometer is equipped with the Microphone Type 4131 or 4133.

I. Calibration.

The combined Spectrometer and Condenser Microphone may be calibrated in the following way:—

*) Refer "Automatic Recording of Voltage Analysis", para A II item 3 or para B II item 6.

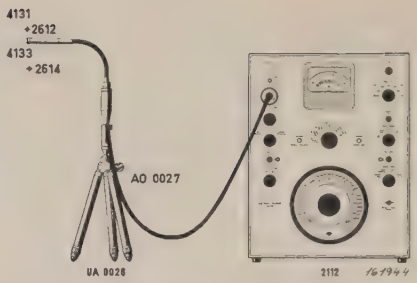


Fig. 3.7. Spectrometer set up as Precision Sound Level Meter.

Microphone 4131 utilized.
Employment of Spectrometer Reference Voltage and Microphone Correction Factor "K". (Information on "K" is given in Fig. 3.5, page 51).

1. Check the microphone polarization voltage (if necessary, see Description, page 32).
2. Connect the Condenser Microphone as shown in Fig. 3.7.
3. The control knobs should be set as mentioned below:—
   INPUT SWITCH: "Condenser Microphone"
   METER RANGE: "Ref."
   METER SWITCH: "Fast"
   "RMS"
   RANGE MULTIPLIER:
   "0 dB × 1"
   FUNCTION SELECTOR:
   "Linear, 2—40000 c/s"
   Control knobs not mentioned can be in any position.
4. Allow a few minutes to warm up.
5. From the calibration chart of the Microphone employed, the correction factor "K" in dB is taken.

Microphone 4133 utilized.
1. Check the microphone polarization voltage (if necessary, see page 32).
2. Connect the Condenser Microphone as shown in Fig. 3.7.
3. The control knobs should be set as mentioned below:—
   INPUT SWITCH: "Condenser Microphone"
   METER RANGE: "Ref."
   METER SWITCH: "Fast"
   "RMS"
   RANGE MULTIPLIER:
   "0 dB × 1"
   FUNCTION SELECTOR:
   "Linear, 2—40000 c/s"
   Control knobs not mentioned can be in any position.
4. Allow a few minutes to warm up.
5. Turn the SENSITIVITY-CONDENSER MICROPHONE potentiometer by means of a screwdriver until the meter pointer deflects to the red mark.

▼

Microphone 4131 utilized.

6. Turn the SENSITIVITY-CONDENSER MICROPHONE potentiometer by means of a screwdriver until the meter pointer deflects to the red mark + "K" dB. If "K" is negative, it has to be subtracted from the value in dB corresponding to the red mark.

II. Adjustment to the Sound Signal.

1. The Condenser Microphone should be exposed to the sound field.
1. METER RANGE switch is turned counterclockwise until a suitable deflection is made on the instrument meter. If a convenient deflection on the meter cannot be obtained by using the METER RANGE switch, the RANGE MULTIPLIER switch may be set to a position with a higher sensitivity, see also Overdriving, page 31.

III. Measuring.

Microphone 4131.

1. Set FUNCTION SELECTOR to "⅓ Octave, 0 dB" or "Octave, 10 dB" as desired.
2. The absolute value of the Sound Pressure Level, or Sound Level (dependent upon the position of the Spectrometer filter switch), can now be read on the instrument meter by using the formula:—

   The deflection in dB on the indicating meter
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR

▼

Microphone 4133.

1. Set FUNCTION SELECTOR to "⅓ Octave, 0 dB" or "Octave, 10 dB" as desired.
2. The absolute value of the Sound Pressure Level, or Sound Level (dependent upon the position of the Spectrometer filter switch), can now be read on the instrument meter by using the formula:—

   The deflection in dB on the indicating meter
   + the number of dB S.L. indicated by METER RANGE
   + the sum of numbers of dB indicated by RANGE MULTIPLIER and FUNCTION SELECTOR
   + the correction factor "K" dB. "K" is the correction factor for the Condenser Microphone, see Fig. 3.5, page 51.

Microphone 4131

Example 1.
Deflection of the meter: 16 dB
Position of METER RANGE: "60 dB S.L."
Position of RANGE MULTIPLIER: "0 dB, × 1"
Position of FUNCTION SELECTOR: "⅓ Octave, 0 dB"
16 dB + 60 dB + 0 dB + 0 dB = 76 dB S.P.L. or S.L.

Example 2.
Deflection of the meter: 10 dB
Position of METER RANGE: "80 dB S.L."
Position of RANGE MULTIPLIER: "— 10 dB × 0.3"
Position of FUNCTION SELECTOR: "Octave, 10 dB"
10 dB + 80 dB — 10 dB + 10 dB = 90 dB S.P.L. or S.L.

Microphone 4133

Example 1.
Deflection of the meter: 2.7 dB
Position of METER RANGE: "60 dB S.L."
Position of RANGE MULTIPLIER: "0 dB, × 1"
Position of FUNCTION SELECTOR: "⅓ Octave, 0 dB"
Correction factor "K": 13.3 dB
2.7 dB + 60 dB + 0 dB + 0 dB + 13.3 dB = 76 dB S.P.L. or S.L.

Example 2.
Deflection of the meter: 10 dB
Position of METER RANGE: "80 dB S.L."
Position of RANGE MULTIPLIER: "— 10 dB × 0.3"
Position of FUNCTION SELECTOR: "Octave, 10 dB"
Correction factor "K": 13.3 dB
10 dB + 80 dB — 10 dB + 10 dB + 13.3 dB = 103.3 dB S.P.L. or S.L.

Calibration or Checking by Means of a Calibrated Sound Source.

An easy way to calibrate or check a measuring arrangement for sound investigation is offered by the employment of the B & K Pistonphone Type 4220 or Noise Source Type 4240.

I. Pistonphone.

The Pistonphone is a compact battery-operated, portable device, designed for the calibration of microphones and measuring set-ups. Further information can be obtained from the respective manual or data sheet.
The procedure to calibrate a measuring arrangement which includes Spectrometer Type 2112 is:—

1. The Spectrometer control knobs should be positioned as follows:—

Microphone 4131 or 4132.	*Microphone 4133 or 4134.*
INPUT SWITCH: "Condenser Microphone"	INPUT SWITCH: "Condenser Microphone"
METER RANGE: "120 dB S.L."	METER RANGE: "100 dB S.L."
RANGE MULTIPLIER: "— 10 dB × 0.3"	RANGE MULTIPLIER: "0 dB, × 1"
FUNCTION SELECTOR: "⅓ Octave, 0 dB"	FUNCTION SELECTOR: "⅓ Octave, 0 dB"
FILTER SWITCH: "Lin."	FILTER SWITCH: "Lin."
METER SWITCH: "RMS, Fast"	METER SWITCH: "RMS, Fast"

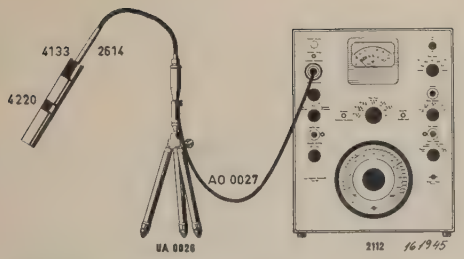


Fig. 3.8. Calibration of measuring arrangement using Pistonphone Type 4220

2. Place Pistonphone on the Microphone Cartridge, (as in Fig. 3.8), and switch on its motor.
3. The indicating meter on the Spectrometer should now deflect to:—

Microphone 4131 or 4132.

The value of S.P.L. given in dB on the calibration chart for the Pistonphone less 110 dB.

▼

Example:

The value of SPL given on the calibration chart: 124.2 dB
The deflection of the indicating meter should then be:—
124.2 dB — 110 dB = 14.2 dB

Microphone 4133 or 4134.

The value of S.P.L. given in dB on the calibration chart for the Pistonphone, less 100 dB, and in addition, less "K".

"K" is the correction factor in dB, *valid* for the Microphone in question.

Example:

The value of SPL given on the calibration chart: 124.2 dB
The correction factor "K" of the Microphone 13.3 dB
The deflection of the indicating meter should then be:—
124.2 dB — 100 dB — 13.3 dB = 10.9 dB

4. Possible deviation has to be corrected by means of the SENSITIVITY — CONDENSER MICROPHONE accessible on the front of the Spectrometer.
5. When the Level Recorder Type 2305 is combined with the Spectrometer, the deflection of its stylus can readily be calibrated, by the Pistonphone. The procedure employed is the same as the one given here for the Spectrometer. The different control knobs of the Level Recorder are operated as outlined in "Automatic Recording of Voltage Analysis", paragraph A. II, page 42. For reading of level on the recording paper refer C. "Reading of Absolute Value from the Spectrogram", page 47.

II. Noise Source.

The Noise Source is designed to give a quick check on measuring arrangements set for sound investigation. The Source is a cartridge in which steel balls generate the noise level. Further information is given in the manual or data sheet for this device.

1. The procedure for employing the apparatus is similar to that given for the Pistonphone, with the exception that the control knobs of the Spectrometer should now be set as follows:—

Microphone 4131 or 4132.

INPUT SWITCH: "Condenser Microphone"
METER RANGE: "100 dB S.L."
RANGE MULTIPLIER: "— 10 dB × 0.3"
FUNCTION SELECTOR: "⅓ Octave, 0 dB"
FILTER SWITCH: "Lin."
METER SWITCH: "RMS, Slow"

Microphone 4133 or 4134.

INPUT SWITCH: "Condenser Microphone"
METER RANGE: "80 dB S.L."
RANGE MULTIPLIER: "0 dB, × 1"
FUNCTION SELECTOR: "⅓ Octave, 0 dB"
FILTER SWITCH: "Lin."
METER SWITCH: "RMS, Slow"

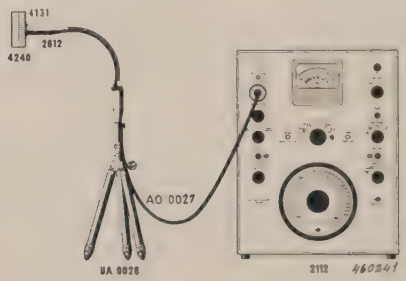


Fig. 3.9. Checking of measuring arrangement by Noise Source Type 4240.

2. The Noise Source is placed on the Microphone Cartridge (refer Fig. 3.9). The outer ring of the Noise Source housing should then be turned through 180°, whereby the noise is generated by the running of the steel balls.
3. The indicating meter of the Spectrometer should now deflect to:—

Microphone 4131 or 4132.

The value of S.P.L. written in dB on the Source housing less 90 dB.

Microphone 4133 or 4134.

The value of S.P.L. written in dB on the Source housing less 80 dB, and further, less "K".

Microphone 4131 or 4132.

Example:

Value of SPL given on the housing: 107 dB

The indicating meter should then deflect to:—

107 — 90 = 17 dB

Microphone 4133 or 4134.

"K" is the correction factor in dB *valid* for the Microphone in question.

Example:

Value of SPL given on the housing: 107 dB

The correction factor "K" of the Microphone: 13.3 dB

The indicating meter should then deflect to:—

107 — 80 — 13.3 = 13.7 dB

4. Accessories

Extension Filter Set Type 1620 (ZS 0146) 65
⅓ Octave Filters 65
Octave Filters 65
Mounting and Connection 65
Other Extension Filters 68

Frequency and Distortion Measuring Bridge Type 1607 68
Specification 70

Condenser Microphones 70
Specification 71

Two-Channel Microphone Selector Type 4408 72
Specification 73

Psophometer Filter ZS 0301 73

Hearing Aid Test Box Type 4212 73
Specification 74

Standing Wave Apparatus Type 4002 75

Vibration Pick-up Preamplifier Type 1606 76
Specification 76

Input Transformer TI 0001 77
Specification 78

Screened Connection Box JJ 0004 78

Connecting Cable AQ 0002 78

4. Accessories

Extension Filter Set Type 1620 (ZS 0146).

When analyses of frequencies below 22 c/s have to be carried out, the Extension Filter Set Type 1620 is utilized in conjunction with the Spectrometer. The Extension Filter Set contains both 1/3 and 1/1 octave filters extending the selective range of the Spectrometer down to 11 Hz (c/s).

Fig. 4.1. Extension Filter Set Type 1620.

1/3 Octave Filters. The Filter Set is furnished with three filters of 1/3 octave bandwidth (3 dB), having center frequencies of 12.5, 16 and 20 Hz (c/s). In Fig. 4.2 a graph is given where typical filter characteristics are shown. The tolerances in the pass-band are within those stated for the 1/3 octave filters in the Spectrometer.

Octave Filter. When the Spectrometer is set to 1/1 octave analysis, the 1/3 octave filters are combined into one 1/1 octave filter with a center frequency of 16 Hz (c/s). The tolerances in the pass-band are within those given for the lower 1/1 octave bands in the Spectrometer.

Mounting and Connection. The Extension Filter Set is built up in drawers and mounted on a chassis. It is available either in a mahogany cabinet as an Extension Filter Set Type 1620 or on a separate chassis, Filter Chassis ZS 0146. The Extension Filter Set Type 1620 can be connected to the Spectrometer terminal FILTER INPUT — EXTENSION FILTER by means of a multi-cored screened cable terminated with a 7-pin plug. The adaptor which is normally mounted in the FILTER INPUT — EXTENSION FILTER, should then be removed and replaced by the seven pin plug of the connection cable. In case the Extension Filter Set should be used with the Spectrum Recorder Type 3315 or the A.F. Response and Spectrum Recorder Type 3332 it is possible to mount the Filter Set internally in the respective cabinets. The

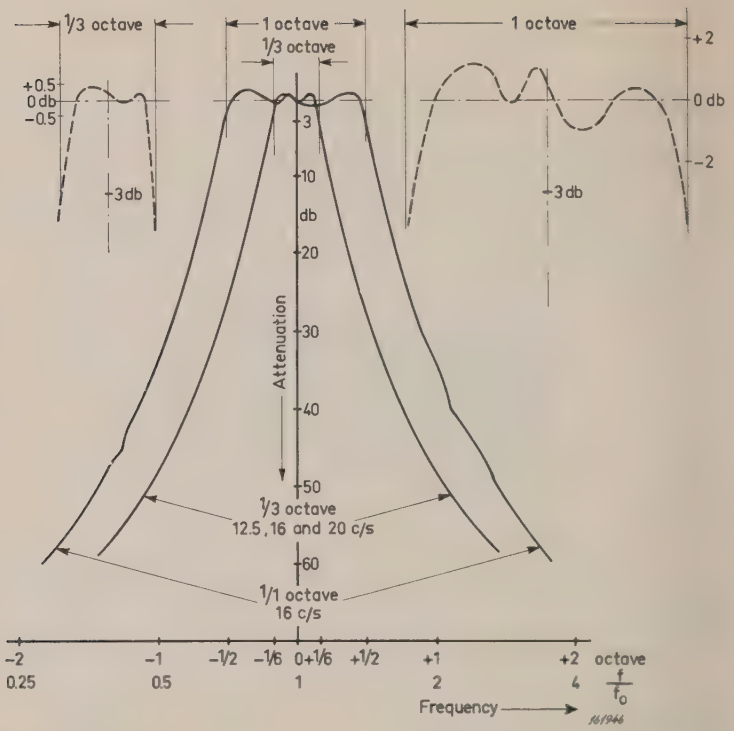
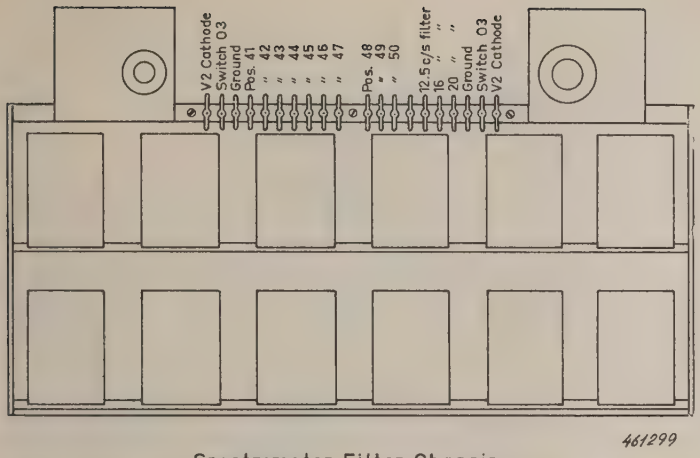


Fig. 4.2. Typical filter characteristics as derived from sine-wave signals of Extension Filter Set Type 1620.

mahogany case is then superfluous, for which reason the Filter Set is delivered on a chassis and without the 7-pin plug on the connecting cable. In this form the Filter Set is termed Filter Chassis ZS 0146. The necessary connections to the Spectrometer Filter Switch should under these circumstances be made internally and as follows. See also Fig. 4.3 where the terminal block on the Spectrometer for the connections to be made is shown, and Fig. 4.4 illustrating the terminal part of the multi-cored cable which has to be connected to the terminal block.

1. The cores "red" and "VI" and also the internal screen Fig. 4.4 are cut off as they must not be connected



Spectrometer Filter Chassis

Fig. 4.3. Sketch of filter chassis in Type 2112 with terminal block (viewed from rear).

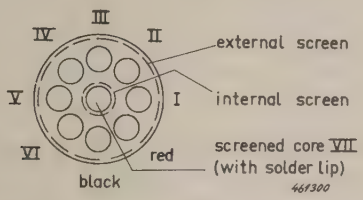


Fig. 4.4. Identification of the cores of the Extension Filter Chassis ZS 0146 connection cable. Cable viewed from free end.

2. The cores (Fig. 4.4) in the multicable and its external screen are connected to the terminal block of the Spectrometer:—

External screen to point	Ground of terminal block
Core Black	20 c/s
- I	12.5 c/s
- II	16 c/s
- III	Ground
- IV	Ground
- V	Ground
- VII (solder lipped)	Switch O3

3. Remove the internal connections (indicated by "12.5", "16" and "20" in Fig. 4.5) from the socket, FILTER INPUT — EXTENSION FILTER. This

has to be carried out, otherwise the built-in Extension Filters ZS 0146 will be short-circuited to ground when the adaptor is inserted which transforms the multi-socket FILTER INPUT — EXTENSION FILTER into a 14 mm coaxial socket.

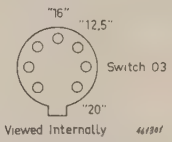


Fig. 4.5. Jack, "Filter Input — Extension Filter".

Other Extension Filters. The points Pos. 41, Pos. 42 - - - Pos. 50 on the terminal block are wired up to the respective positions of the FILTER SWITCH in such a manner that Pos. 41 is wired to the position of the FILTER SWITCH which is situated immediately after (clockwise, front plate view) position "Lin." and so on till Pos. 50 on the terminal block which is wired with the Filter Switch position placed immediately before position "12.5". The positions mentioned are normally connected to ground to avoid induced noise. By removing this ground connection the positions can be used for other external filters.

NOTE: A DC voltage of approximately 75 Volts is present on point "V2 Cathode" and "Switch O3" of the terminal block. This DC voltage is blocked by condensers in the Extension Filter Set Type 1620 and ZS 0146 but should be taken into consideration when using other external filters.

Frequency and Distortion Measuring Bridge Type 1607.

The Frequency and Distortion Measuring Bridge is an instrument designed for selective attenuation of any frequency within the range 20—20000 Hz (c/s).

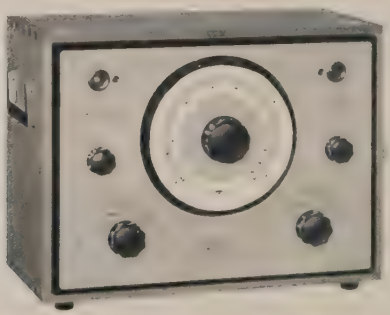


Fig. 4.6 Frequency and Distortion Measuring Bridge Type 1607.

It consists of a parallel-T network, the resistive components of which are continuously variable within each of six frequency ranges selected by a switch. The selected frequency is easily read from a large scale of 280°. A compensation network which allows the distortion of a signal to be measured in one reading follows the parallel-T network. This compensating network provides a linear frequency response to within ± 1 dB in the frequency range from the 2nd to the 7th harmonic of the signal. See also Fig. 4.7. Used in conjunction with the Spectrometer it provides a quick and efficient method of measuring frequencies within its range. The Bridge is connected to the FILTER INPUT and FILTER OUTPUT sockets of the Spectrometer, the output amplifier and indicating meter of which will then function as an indicator. The Bridge can also be connected so that the complete Spectrometer operates as indicator. An auxiliary control enables an accurate balance of the Bridge to be made whereby an attenuation of 80 dB or more of one of the frequencies in a signal can be obtained.

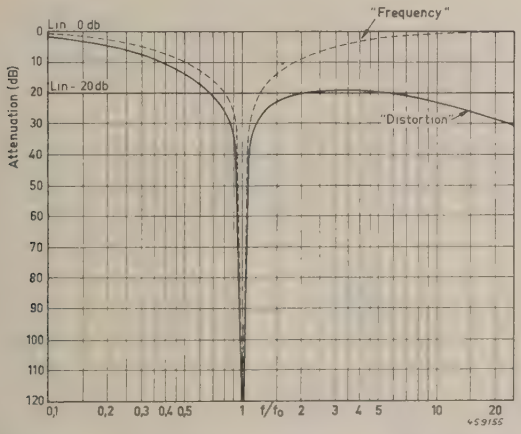


Fig. 4.7. Frequency characteristics of Frequency and Distortion Measuring Bridge. In position "Distortion" the distortion factor k is measured. For normal frequency rejection the characteristic "Frequency" is selected.

When the Bridge is inserted between the input and output amplifier of the Spectrometer, reading of distortion factors as low as 0.1 % can be obtained in one operation. By utilizing the true r.m.s. reading from the Spectrometer the correct distortion factor is read as the r. m. s. value of the harmonics. If measurements of lower distortion factors are required the "Output" of the Bridge should be connected to the "Input" of the Spectrometer. This arrangement enables the measurement of distortion factors lower than 0.01 %. In

part Application of this book is described an application utilizing the latter method.

SPECIFICATION

Frequency Ranges: 1. 20—63 Hz (c/s), 2. 63—200 Hz (c/s), 3. 200—630 Hz (c/s), 4. 630—2000 Hz (c/s), 5. 2000—6300 Hz (c/s), 6. 6300—20000 Hz (c/s).

Frequency Scale Accuracy: Better than 1 %.

Scales: Easily read, 280°, calibrated 20—63 and 63—200 with suitable overlaps.

Response of Compensation Network: In the "Distortion" position the attenuation of the pass-band is 20 dB ± 1 dB from the 2nd to the 7th harmonic of the rejected frequency.

Attenuation of the Rejected Frequency: Better than 80 dB.

Impedances:

Input: Between 5.5—18 kΩ depending on scale setting.

Output: Dependent upon control settings, but should be connected to an external impedance of not less than 100 kΩ.

Condenser Microphones.

When employing one of the B & K Condenser Microphones in conjunction with the Spectrometer a complete equipment for high precision measurement and analysis of sound is procured. The B & K Condenser Microphone program is very extensive and is constantly progressing. The predominant

Fig. 4.8. Condenser Microphones

part of the program is centred around the Microphone Cartridge and the associated Cathode Follower (which constitute the Condenser Microphone) but includes a wide range of accoutrement which make it possible to cover the majority of sound investigations. Due to the extensive program only some data for the Microphone Cartridges and their associated Cathode Followers are listed here:—

SPECIFICATION

Microphone Cartridge Type	4131	4132	4133	4134	4135	4136
Frequency Response. Flat.*) Free-field Pressure Random incidence and pressure	20 Hz (c/s) to 18 kHz (kc/s)	20 Hz (c/s) to 7 kHz (kc/s)	20 Hz (c/s) to 40 kHz (kc/s)	20 Hz (c/s) to 20 kHz (kc/s)	30 Hz (c/s) to 100 kHz (kc/s)	30 Hz (c/s) to 80 kHz (kc/s)
Sensitivity. Approx.*)	5 mV/μbar (—46 dB re. 1 V/μbar		1 mV/μbar (—60 dB re. 1 V/μbar		0.2 mV/μbar —74 dB re. 1 V/μbar	0.1 mV/μbar —80 dB re. 1 V/μbar
Dynamic Range, re. 2×10^{-4} μbar "A"-weighted to 4 % distortion	15—146 dB		32—160 dB		64—174 dB	70—180 dB
Maximum Safe Sound Pressure, re. 2×10^{-4} μbar	165 dB		180 dB		185 dB	
Temperature Coefficient	Less than ± 0.01 db per °C					
Construction. Cylindrical. Outside diameter	23.77 mm (0.936")		13.2 mm (0.52")		7.4 mm (0.29")	
Ambient Pressure Coefficient. 100 mm Hg pressure decrease equals a sensitivity increase of	0.2 dB		0.1 dB		Less than 0.1 dB	
To be employed with Cathode Follower Type	2612 or 2613		2614 or 2615		2614 or 2615 + Adaptor UA 0035	

*) Individually calibrated.

Cathode Follower Type	2612 — 2613	2614 — 2615	
Input Impedance	Approximately 270 MΩ paralleled by 3 μμF.	Approximately 700 MΩ paralleled by 2.5 μμF.	
Self-Generated Noise Level	Less than 30 μV for the frequency band 20—20000 c/s (input loaded by 60 μμF).	Less than 40 μV for the frequency band 20—20000 c/s (input loaded by 20 μμF).	
Sensitivity to Vibration	(Cathode Follower with Microphone Cartridges 4131/4132). Less than 85 dB re. 0.0002 dyn/cm² for 1 G excitation in any direction.	(Cathode Follower with Microphone Cartridges 4133/4134). Equivalent to 88 dB re. 0.0002 dyn/cm² for 1 G excitation.	
Sensitivity to Sound Fields	Loaded with dummy cartridges and placed in a 130 dB Sound Field the Cathode Follower output is 50 dB below normal microphone output.		
Working Temperature	2612 — 2613 From below — 40° C to above 100° C.	2614 From below — 40° C to above 150° C (above 250° C intermittent).	2615 From below — 40° C to above 100° C.

To give an impression of the area of application, some of the most important accessories are mentioned:—

Artificial Ear Type 4151, Artificial Voice Type 4215, Pistonphone Type 4220, Microphone Calibration Apparatus Type 4142, Noise Source Type 4240, Nose Cones (various types), Wind Screen UA 0050, Probe Microphone Kit UA 0040, Floor Stand UA 0026, Electrostatic Actuators (various types), Extension Cables (various lengths) etc.

Two-Channel Microphone Selector Type 4408.

This apparatus is designed so that the output from one or the other of two

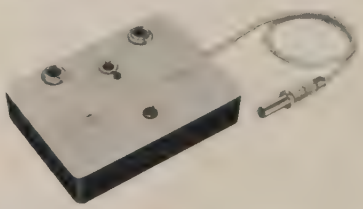


Fig. 4.9. Two-Channel Microphone Selector Type 4408.

Condenser Microphones can be automatically or manually switched successively into a single amplifier. A recording of two phenomena, e.g. the sound pressure at two different points in a sound field, can thus be measured on the B & K Level Recorder simultaneously.

The Microphone Selector is housed in a metal box and contains the components necessary for the elimination of hum and cross-talk effects and a toggle switch which operates a relay. When the Selector Type 4408 is operated manually, the toggle switch is employed. The switch then operates the relay which in turn switches the two inputs of the Microphone Selector to the single output. The Microphone Selector may also be remotely controlled. The toggle switch must then be in position "2 Ext.", and the external control switch connected to the terminals marked EXTERNAL CONTROL by means of a two-cored cable, thereby making the external switch replace the function of the toggle switch.

A typical application of the Two-Channel Microphone Selector is given on page 90 "Noise Indication in Production Line Testing of Domestic Equipment".

Some Technical Data:—

The Two-Channel Microphone Selector is designed specially for use with the B & K Condenser Microphones.

The cross-talk effect is negligible. Due to coupling in the H.T. supply (between the two anodes) the effect of cross-talk is greatest at the lower frequencies, but is reduced by more than 80 dB at 20 Hz (c/s).

Transients, occurring from switch-over, may last for approximately 100 m sec.

N.B. Due to the series heating of the tubes, the Microphone Selector can only be used when both Microphones are connected.

Psophometer Filter ZS 0301.

This Filter has been designed for noise measurements in radio broadcasting

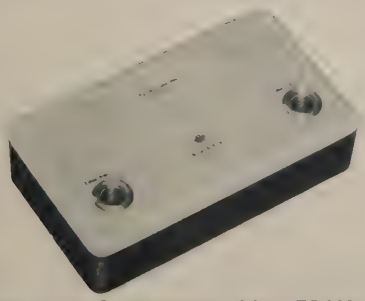


Fig. 4.10. Psophometer Filter ZS 0301.

audio systems. It is a special frequency weighting filter as required by C.C.I.F. (C.C.I.T. C.C.I.T.T.). The input impedance is somewhat frequency dependent (2ooo—600 ohms).

The FILTER INPUT should be connected to a low source impedance (10 ohms or lower) and a maximum voltage of 3 volts approx. (Max. Crest-factor 5). The FILTER OUTPUT should be loaded by 146 kohms. When the filter is used in connection with the Audio Frequency Spectrometer Type 2112 (as "Extension Filter") the filter input condition is fulfilled. A load resistance of 162 kohms should be connected in parallel with the filter output to obtain matching. Notice that, using cables other than the B & K AO 0013 or AO 0014 for connecting the filter, the cable capacity should be lower than 250 pF in order to keep the filter characteristics within the tolerances permitted in the standards.

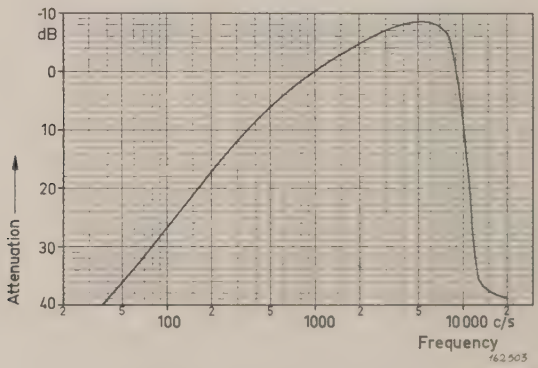


Fig. 4.11. Typical frequency characteristic of ZS 0301.

Hearing Aid Test Box Type 4212.

In measuring the free-field response and distortion of complete hearing aids and small microphones the Hearing Aid Test Box is an indispensable equipment.

The Test Box is portable and consists of a small anechoic chamber with a built-in loudspeaker and regulating microphone as well as an artificial ear, which contains a 2 cc coupler, specially designed for use both on hearing aids with built-in earphones and the conventional types. The artificial ear, with the 2 cc coupler, is in accordance with the ASA standard Z 24. 9 as well as the international IEC standard. The regulating microphone is used in a compressor (servo) circuit allowing a constant sound pressure level to be maintained at the hearing aid microphone. The regulating microphone is so situated that it does not influence the practically free sound field conditions

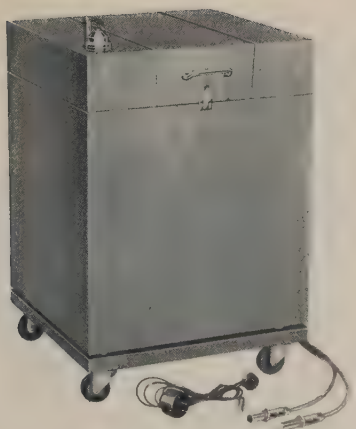


Fig. 4.12. Hearing Aid Test Box Type 4212.

that exist in the Test Box. By placing the hearing aid earphone in the artificial ear it is possible to measure the overall characteristics of the device with relation to acoustical input and output.

In part Application of this book a measuring arrangement is described using the Hearing Aid Test Box as part of the set-up.

SPECIFICATION

Frequency Range: 150 Hz (c/s)—5000 Hz (c/s).

Dynamic Range: 40 dB to approx. 90 dB re. 2×10^{-4} μbar.

Uniformity of Sound Field.

The free field sound level at the measuring point is equal to that at the regulating microphone to within the following tolerances. At 200 Hz (c/s): $\pm$ 0.2 dB, at 2000 Hz (c/s): $\pm$ 0.5 dB, and at 5000 Hz (c/s): $\pm$ 3 dB.

Effective Test Area: 8 cm $\times$ 6 cm (3″ $\times$ 2.5″).

Acoustic Coupler: The artificial ear includes a 2 cc coupler.
Other couplers can be supplied, such as:—
6 cc ASA coupler: ASA Type 1, Z 24.9/1949.
6 cc NBS coupler: NBS 9A = ASA Z 24.5/1951.

Loudspeaker: 8 watt specially selected. Moving coil impedance 3.2 Ω at 400 Hz (c/s).

Outside Dimensions of Test Box:
53 (width) $\times$ 53 (depth) $\times$ 80 (height) cm
21 (width) $\times$ 21 (depth) $\times$ 31 (height) inches

Standing Wave Apparatus Type 4002.

The absorption properties of materials with regard to sound can be measured for zero degree incidence with a Standing Wave Apparatus, when this is employed in conjunction with the Spectrometer. The frequency range

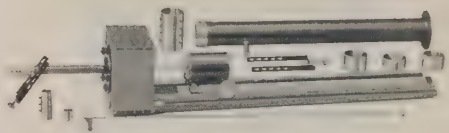


Fig. 4.13. Standing Wave Apparatus Type 4002.

covered with the Apparatus is 90 Hz (c/s) to 6500 Hz (c/s). Absorption coefficients between approximately 2 % and 100 % can be read on a special scale on the indicating meter of the Spectrometer.

The Standing Wave Apparatus consists of a tube in one end of which is mounted a loudspeaker and in the other end a holder for placing discs of the material under investigation. A moveable Probe Microphone enables the sound pressure level to be measured at any point in the tube axis, i.e. at any point of the standing wave.

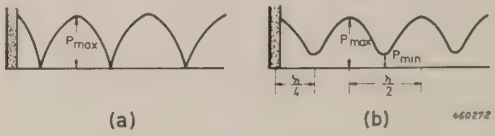


Fig. 4.14. Standing Waves.
(a) No absorption.
(b) With absorption.

The standing wave is built up of the direct sound from the loudspeaker and the reflections from the material terminating the other end of the tube. If the termination is a material acting as a completely rigid wall, a complete reflection of the sound wave will be obtained, and the result will be a pure standing wave with minima equal to zero, vide Fig. 4.14a. When the termination consists of an absorbent material, only part of the wave will be reflected, therefore the minima will no longer be zero, Fig. 4.14b. The ratio between maxima and minima is determined purely by the absorption of the terminating material. This ratio can be found by measuring two successive maximum and minimum values of the sound pressure with the probe microphone.

In part Application of this book is described a measuring arrangement in which the Standing Wave Apparatus is employed.

Vibration Pick-up Preamplifier Type 1606.

When the Spectrometer is utilized in vibration measurements a preamplifier for the B & K Accelerometers is a necessity. Therefore, the Vibration Pick-up

Fig. 4.15. Vibration Pick-up Preamplifier Type 1606.

Preamplifier has been designed. It is connected to the CONDENSER MICROPHONE input, from where the necessary power to the Preamplifier is also supplied.

A measuring arrangement built up of one of the B & K Accelerometers, the Preamplifier and the Spectrometer allows all three values of vibration (i.e. displacement, velocity and acceleration) to be measured in the frequency range 2 Hz (c/s) to 40 kHz (kc/s).

The Preamplifier contains, along with the amplifier stages, integration networks which make it possible to convert the acceleration signal from the Accelerometer into a velocity or displacement dependent signal. For calibration of the complete measuring arrangement the Preamplifier is furnished with a built-in exciter calibrating at 1 g*).

A measuring arrangement together with an example of a measurement where the Preamplifier is employed in conjunction with the Spectrometer, can be found in part Application of this book.

SPECIFICATION

Frequency Range:	2 Hz (c/s)—100000 Hz (c/s) at 0 dB amplification.
Amplification (voltage):	Adjustable, 0 to 38 dB.
Input Impedance:	200 MΩ, paralleled by 50 pF approx
Input Attenuator:	2 steps of 40 dB.
Max. Input Voltage:	10 Volts peak for 0 dB amplification.
Dynamic Range:	Acceleration, 2×10^{-3} g to 500 g approx., or 10×10^{-3} g to 2000 g approx. dependent on the type of Accelerometer utilized.

*) 1 g = acceleration of gravity.

Input Transformer TI 0001.

By connecting this Transformer to the AMPLIFIER INPUT of the Spectrometer a symmetrical input with respect to ground can be obtained. The Transformer has two input impedances which are selected by a switch INPUT IMP. The impedances are 20 kΩ and 600 Ω. A third position of the switch allows a grounded middle point of the "Input" to be utilized. Vide Fig. 4.17.

Fig. 4.16. Input Transformer TI 0001.

To give a straight frequency response, 10—20000 Hz (c/s) $\pm$ 0.2 dB, the "Output" of the Transformer should be properly loaded. First, to ensure that a low capacity is connected to the OUTPUT of the Transformer the special low-capacity cable AO 0018 delivered with the Transformer should always be used when connected to the Spectrometer. Secondly, to ensure the proper resistive load, the toggle switch on the Transformer should be set in position "Int. Load". Great efforts are made to make the Transformer insensitive to externally inductive stray fields, therefore it has been furnished with a double mumetal screen. Due to this the sensitivity to a field of 50 Hz (c/s)

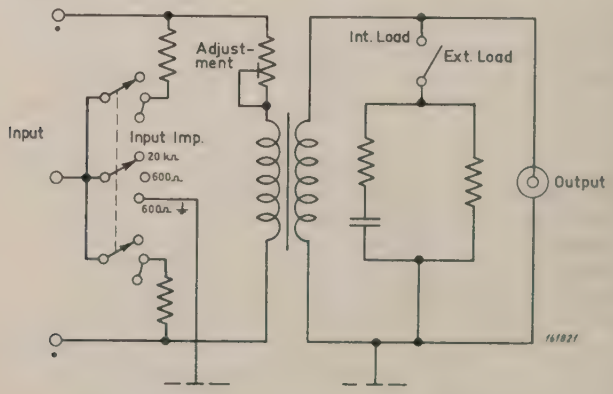


Fig. 4.17. Schematic diagram of Input Transformer.

and 50 gauss corresponds to less than 1 mV on the "Output" terminal when the Transformer has an open INPUT terminal and is located in the most unfavourable position in the field.

The transformer ratio 1 : 1 can, if necessary, be adjusted by a potentiometer "Adjustment" accessible at the bottom. The Transformer is correctly pre-adjusted at the factory.

SPECIFICATION

Frequency Range:	10 Hz (c/s)—20 kHz (kc/s) within ± o.2 dB.
Transformer Ratio:	1 : 1.
Input Impedance:	20 kΩ aprox. with INPUT IMP in position "20 kΩ". 600 Ω ± 2 % with INPUT IMP in position "600 Ω" or "600 Ω ⏚".
Balance (approx.):	Common-mode signal rejection. (Measured in phantom circuit). 80 dB at 200 Hz (c/s). 60 dB at 2 kHz (kc/s). 40 dB at 20 kHz (kc/s).
Maximum Input Voltage:	1.6 V / Hz (c/s) up to a maximum of:— 100 V with INPUT IMP in position "20 kΩ" 20 V with INPUT IMP in position "600 Ω" or "600 Ω ⏚".
Distortion (non-linear):	Less than 1 % when voltage on INPUT is less than o.8 V / Hz (c/s).

Screened Connection Box JJ 0004.

When more complex measuring arrangements are built up of B & K instruments it is often necessary to make multiple connections. For this purpose

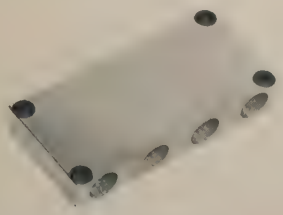


Fig. 4.18. Screened Connection Box JJ 0004.

the Connection Box is a very useful accessory. The Box contains four screened sockets which are all connected in parallel (in multiples). These terminals match the normal B & K Screened Connecting Cables.

Connecting Cable AQ 0002.

This Cable is intended to be used when the Filter Switch of the Spectrometer has to be automatically controlled from the B & K Level Recorder.

5. Combined Units

Audio Frequency Spectrum Recorder Type 3315.

The Audio Frequency Spectrum Recorder consists of the Spectrometer Type 2112 and the Level Recorder Type 2305 mounted together in a 19″ rack. The Filter Switch of the Spectrometer is electrically operated from the Level Recorder. This arrangement allows the automatic recording of spectrograms to be carried out on frequency calibrated papers Types QP 1123, 0123, and 0423.

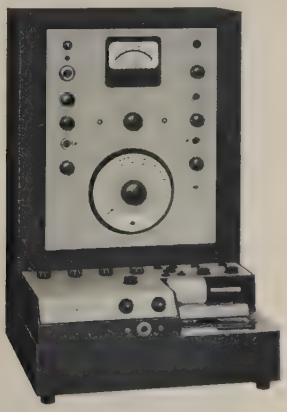


Fig. 5.1. Audio Frequency Spectrum Recorder Type 3315.

The operation of the Unit is the same as described under "Operation" with the exception that it is unnecessary to connect a cable (AQ 0002) between the Spectrometer and the Level Recorder to operate the Filter Switch. This connection is a permanent one, placed internally in the Audio Frequency Spectrum Recorder Type 3315. The automatic switching is commenced and stopped by the knob AUTOMATIC SWITCHING on the Spectrometer similar to when the Spectrometer and Level Recorder are not combined in a console. For a description of the separate instruments of the combined Unit, the reader is referred to the respective paragraphs in the individual instruction books.

A. F. Response and Spectrum Recorder Type 3332.

Following the line of B & K Combined Units for automatic measurements, a further unit namely the A. F. Response and Spectrum Recorder Type 3332 has been designed. It is a combination of the Beat Frequency Oscillator Type 1022, the Audio Frequency Spectrometer Type 2112 and the Level Recorder Type 2305, all of which can be driven synchronously. The paper types are equivalent to those employed by the Audio Frequency Spectrum Recorder Type 3315.

Fig. 5.2. A.F. Response and Spectrum Recorder Type 3332.

The Beat Frequency Oscillator scanning system is coupled mechanically to the paper drive of the Level Recorder via an internal chain, while the switching action of the Spectrometer filters is operated electrically via the same drive. The operation of Spectrometer combined with the Level Recorder is similar to that described under "Operation" in this book, with the exception of connecting a cable (AQ 0002) between the Spectrometer and the Level Recorder for operation of the Filter Switch. The connection is the same as that in the Audio Frequency Spectrum Recorder Type 3315, i.e

permanent and internal. For operation of the Beat Frequency Oscillator Type 1022 in combination with the Level Recorder Type 2305 the user is referred to the manual for the Beat Frequency Oscillator Type 1022. A description of each instrument can be found in their Instruction Manuals.

Application.

By employing the Combined Units Type 3315 or 3332 almost any desired acoustical, electro-acoustical or electrical measurement in the audio frequency range can be carried out and recorded.

The single instruments can be used separately or together in various combinations. An example of an interesting application of the Type 3332 is selective measurements of the frequency characteristic of four-terminal networks, which can be carried out automatically.

Selective measurements are of especial importance when the four-terminal network is a circuit where the noise level might be too high to obtain reliable non-selective measurements, or when the various harmonics of a system are of interest. One of the many applications similar to the latter method can be seen under part Application, page 103.

6. Applications

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6. Applications

In order to give a general view of the possible applications of the Audio Frequency Spectrometer Type 2112 as a separate measuring instrument, or when combined with other equipment, some of the most important and employed measuring arrangements are outlined in the following.

For acoustical applications the Spectrometer should be equipped with one of the B & K Condenser Microphones suitable for the measurements in question. For information concerning these and other instruments used in conjunction with the Spectrometer, reference should be made to part Accessories in this book or to the respective leaflets and manuals.

Distortion Measurements.

The non-linear distortion factor of a four-terminal network can be directly measured by a single measurement when the Spectrometer Type 2112 is used as an R.M.S. tube voltmeter in conjunction with the B & K Frequency and Distortion Measuring Bridge Type 1607, vide Fig. 6.1. In this measuring arrangement the B & K Beat Frequency Oscillator (B.F.O.) Type 1022 is used as signal generator.

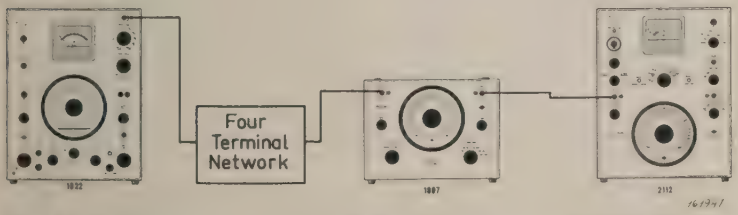


Fig. 6.1. Measuring arrangement suitable for non-linear distortion measurements.

To determine the distortion factor the complete signal has to be measured by the Spectrometer, the indicating meter of which should be adjusted to give full deflection (100 %). When blocking up the fundamental of the measured signal by the Frequency and Distortion Measuring Bridge the factor can now be read in % from the Spectrometer. The B.F.O. has a

distortion factor of o.1 % in the middle frequency range when unloaded. and is thus well-suited for normal distortion measurements where the distortion of the network being tested is greater than o.5 %.

The Audio Frequency Spectrometer used as Bridge Indicator.

With bridge measurements in the audio frequency range, it is advantageous to have a selective indicator in the bridge network, as the disturbing noise level is proportional to the square-root of the instrument bandwidth. The

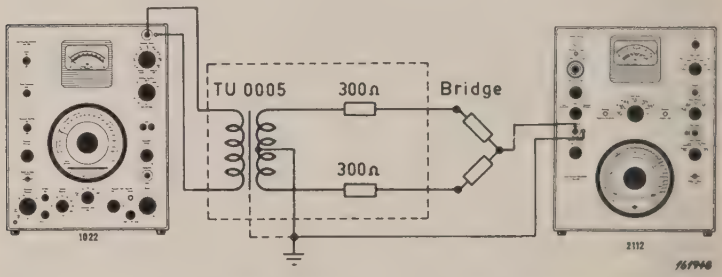


Fig. 6.2. Spectrometer used as bridge indicator.

only requirement the bridge must satisfy is that one diagonal point can be grounded as shown in Fig. 6.2. This requires the bridge to be supplied from an oscillator via a balanced transformer as the output of signal generators is often unbalanced. The measuring set-up indicated shows a B & K Beat Frequency Oscillator used as a signal generator and an Output Transformer TU 0005 which ensures the symmetrical output from the Oscillator.

If the Input Transformer TI 0001 is used in conjunction with the Spectrometer a bridge indicator with balanced input is obtained, enabling bridge measurements to be carried out on bridges which can be loaded with 20 kΩ. In the latter case the balanced transformer in the signal generator output is not necessary.

Due to the selectivity and high sensitivity of the Spectrometer it is excellent as an indicator in bridge measurements. Also, by employing the Spectrometer as a selective indicator it is possible to vary the oscillator frequency to some extent (1 octave or ⅓ octave) without changing the setting on the Spectrometer.

Spectrograms.

The most important application of the Audio Frequency Spectrometer when

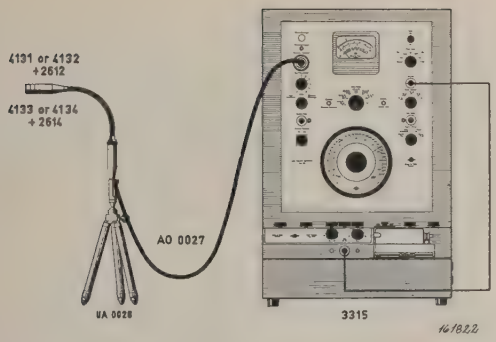


Fig. 6.3. Combination for recording of sound spectrograms.

combined with the B & K Level Recorder Type 2305 is the automatic recording of sound spectrograms.

Some typical spectrograms measured by means of the set-up in Fig. 6.3, are shown in the following. The Spectrometer and the B & K Level Recorder Type 2305 are in this case combined in the Spectrum Recorder Type 3315.

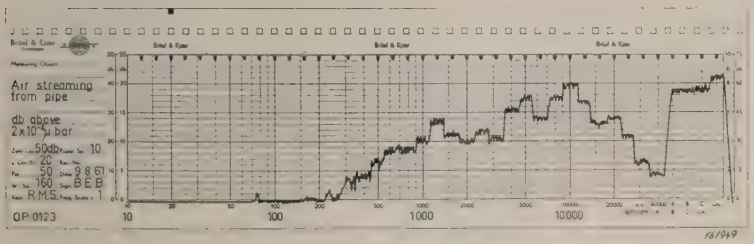
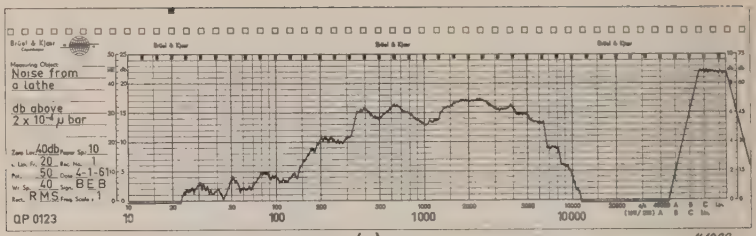


Fig. 6.4. Noise spectrum produced by stream of air, 1/3 octave analysis.

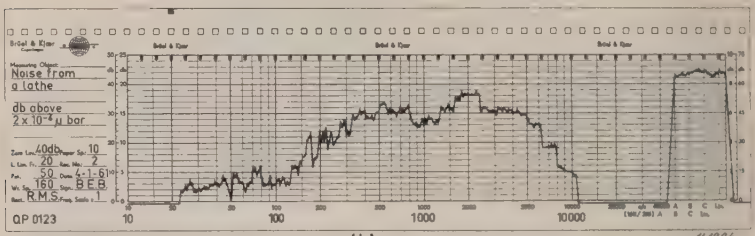
Fig. 6.4 shows a characteristic spectrum of the sound produced by air streaming out of a system of pipes. As can be seen this type of noise consists almost entirely of high frequencies.

Fig. 6.5 shows the spectrogram of the noise radiated from a lathe. The three different curves are recorded with different writing speeds on the Recorder. It is seen that the curve is considerably smoother when a low writing speed is employed. With a high writing speed all the small variations in the sound pressure level become quite pronounced.

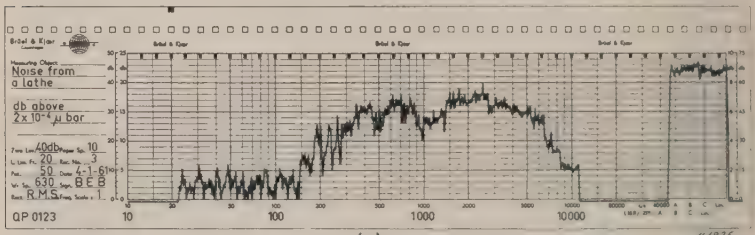
Fig. 6.6; in this case the Spectrum Recorder has been operating just above its



(a) 161823



(b) 161824



(c) 161825

Fig. 6.5. Spectrograms of noise radiated from lathe.
(a) Writing speed 40 mm/sec.
(b) Writing speed 160 mm/sec.
(c) Writing speed 630 mm/sec.

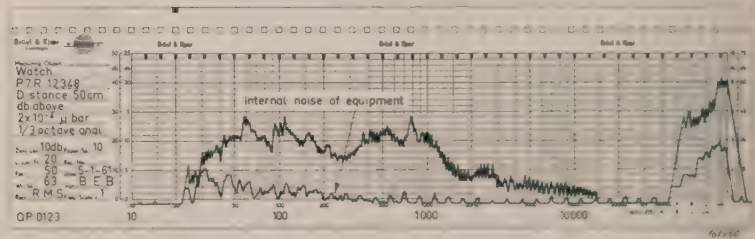


Fig. 6.6. Noise spectrum obtained from a watch. The lower curve gives the internal noise level of the equipment.

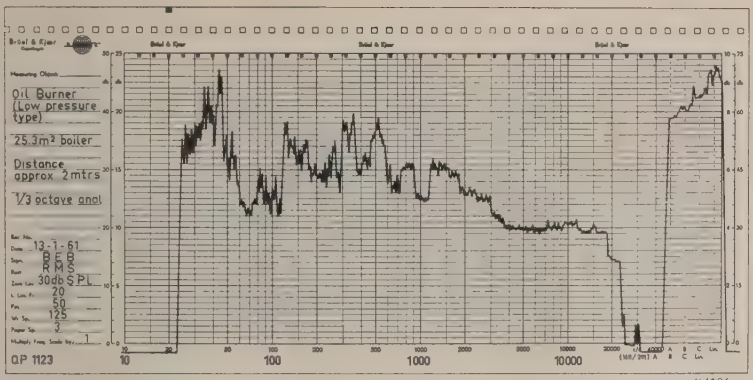


Fig. 6.7. Spectrogram of noise from an oilburner.

own noise level, i.e. above the lowest level at which measurements can be taken. The curve beneath the noise level of the watch is a recording of the internal noise of the complete measuring system.
Additional Brüel & Kjær reference literature: Technical Review, No. 2—1957.

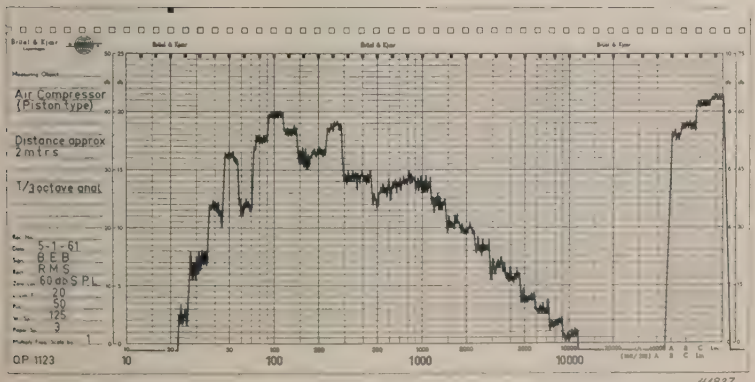


Fig. 6.8. Spectrogram of noise from an air compressor.

Measurements of Typewriter Noise.

The noise produced by typewriters in modern offices is often considered a serious problem, hence the endeavour in recent years to make silent typewriters

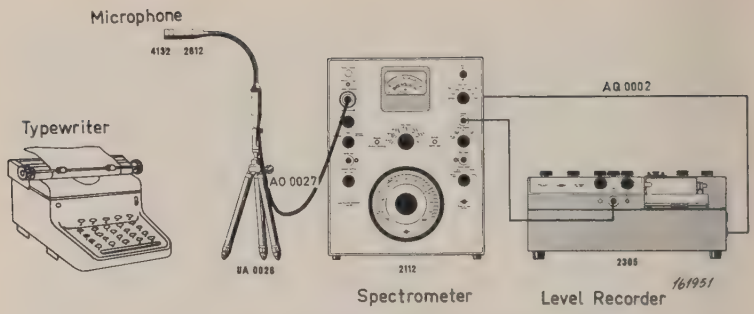


Fig. 6.9. Set-up for measurement of typewriter noise.

The combination of the Spectrometer Type 2112, the B & K Level Recorder Type 2305 and one of the B & K Condenser Microphones constitutes a very convenient unit for the measurement of typewriter noise, as this instrumentation makes it possible to record the analyses of not only the arithmetical average value of the radiated noise but also its r.m.s. and half

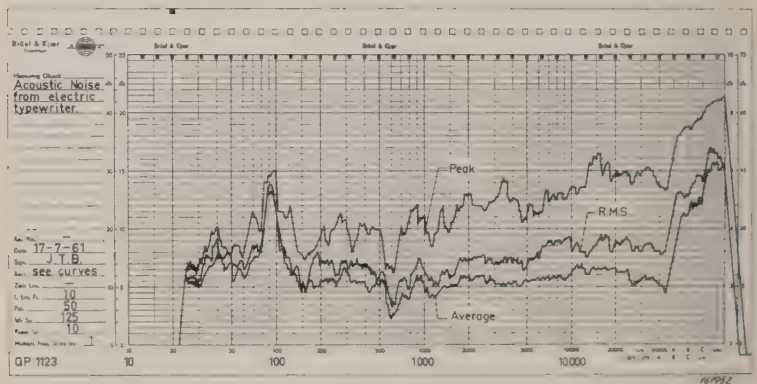


Fig. 6.10. Spectrogram of noise produced by a typewriter.

peak-to-peak value in frequency bands of ⅓ or 1/1 octave. The character of the noise as well as the annoying effects can then be much better judged than they can from ordinary measurements of the arithmetical average value. Fig. 6.10 shows a spectrogram taken which gives the noise produced by an electric typewriter with a distance of approximately 0.5 m between the microphone and the typewriter.

Analysis of Fluctuating Noise.

In workshops, offices, streets, airports etc., the noise level varies considerably throughout the day so one sound measurement at a particular time is almost meaningless. A statistical approach is then necessary to express data which is otherwise difficult to describe.

The Spectrometer Type 2112 is used to select the frequency bands of interest and the signal is fed to a Level Recorder Type 2305.

The writing arm of the Level Recorder scans a set of twelve contacts which in turn actuate counters in the Statistical Distribution Analyser Type 4420. Information concerning sound levels is thus resolved into twelve class intervals and a numerical display of the data presented. From this, the mean level and its standard deviation are easily calculated.

Should a time chart of the phenomenon be required from the recorder, this can be run off simultaneously but is not normally necessary. Frequency-dependent charts cannot be made as the Spectrometer is not synchronized with the Level Recorder for this kind of measurement.

(See also B & K Technical Review No. 1-1964).

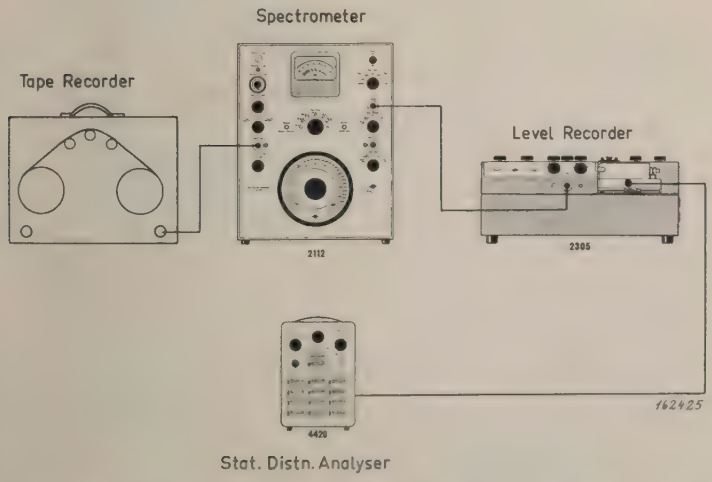


Fig. 6.11. Making a statistical analysis of tape recorded sound using a Level Recorder and a Statistical Distribution Analyser Type 4420. Apart from convenience, tape recording the sound has the advantage that it can be played back again and again through different filters in the Spectrometer.

Noise Indication in Production Line Testing of Domestic Equipment.

An example of the use of the Audio Frequency Spectrum Recorder Type 3315 in production line testing is given in the following.

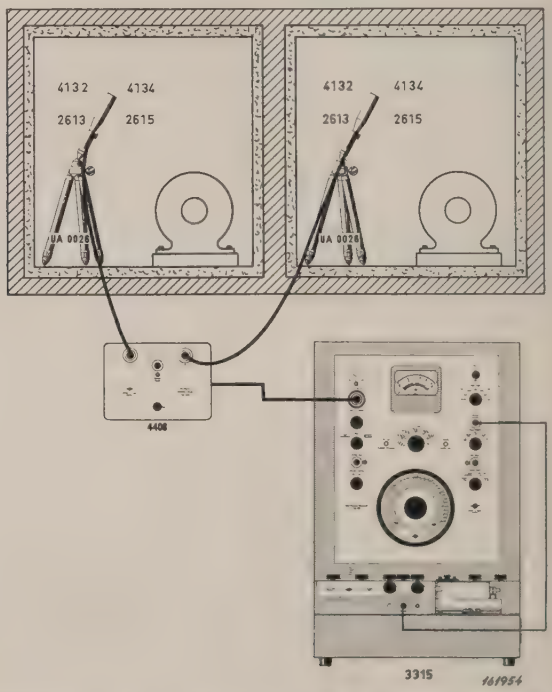


Fig. 6.12. Noise testing of domestic apparatus on a production line.

Faults in rotary machinery can be detected by the sound radiated. Abnormal peaks of sound at certain frequencies often give the inspector a good idea of where to look for the fault. At the same time noise elimination can be performed when spectrograms are taken of the machinery under test. The measurements can be carried out as shown in Fig. 6.12. In two measuring chambers (acoustically treated to give the same response) two B & K Condenser Microphones are installed. The rooms must be well insulated from airborne as well as impact sounds.

With the employment of a Two-Channel Microphone Selector Type 4408, the switching-over from measurements taken in one of the chambers to measure-

ments in the other can be readily carried out. By this means it is possible to replace the apparatus tested in room 1, while measurements are carried out on the apparatus in room 2, giving a quick and reliable check on the acoustical performance of the equipment. Typical units which can be checked in this way are relatively small electric motors, refrigerators, vacuum cleaners, etc.

Additional Brüel & Kjær reference literature: Technical Review, No. 2—1957.

Measurement of Reverberation Time.

The Spectrometer and the B & K Level Recorder constitute very important parts in equipment intended for determination of reverberation time as the measurements can be carried out selectively, thus reducing the influence of background noise, while the sound decay in the room under examination is rendered as a slope on paper recorded by the Level Recorder.

Several methods of exciting the room can be used depending on the number of measurements to be carried out. If only a few measurements are to be made, a pistol or something similar is the simplest form of sound source.

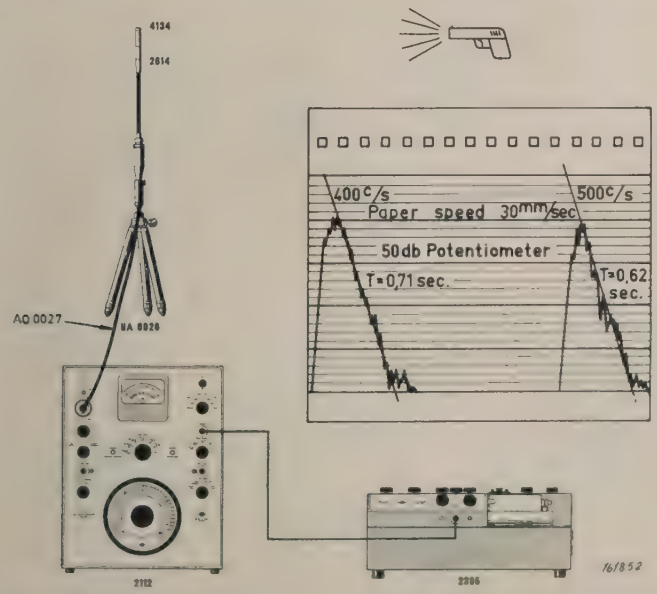


Fig. 6.13. Measuring arrangement for recording of reverberation time. Pistol used as sound source.

When utilizing this method the receiving part of the equipment should always contain a selective instrument such as the Spectrometer which enables measurements to be carried out at different frequencies. In Fig. 6.13 can be seen a measuring arrangement together with an example of two recorded decay curves. The receiving part of the measuring set-up consists of one of the B & K Condenser Microphones, the signal from which is fed to the Spectrometer, and further to the Level Recorder Type 2305 which then records the output signal from the Spectrometer.

When many measurements have to be carried out, for example in a concert hall, a measuring equipment which works automatically will undoubtedly be the most rational solution. In such an arrangement the gun has to be substituted by a sound source which can be conveniently controlled.

Two different methods of signal generation are suitable for this:

1. A frequency-modulated (warbled) oscillator (1022), or a narrow band noise generator (1024), as shown in Fig. 6.14
   or
2. A wideband random noise generator (1402) and a Band-pass Filter Set (1612), shown in Fig. 6.15, which together provide bands of noise.

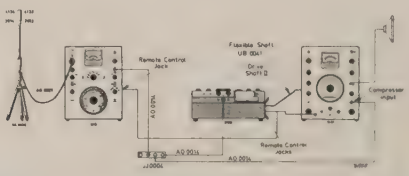


Fig. 6.14. Measuring arrangement for automatic recording reverberation time.

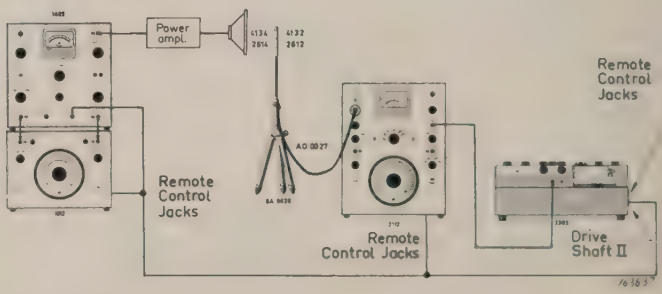
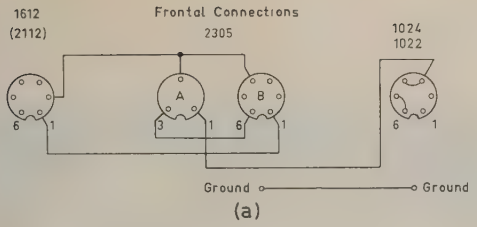


Fig. 6.15. Measuring arrangement for automatic recording of reverberation time, carried out by a wideband random noise generator and a band-pass filter set.



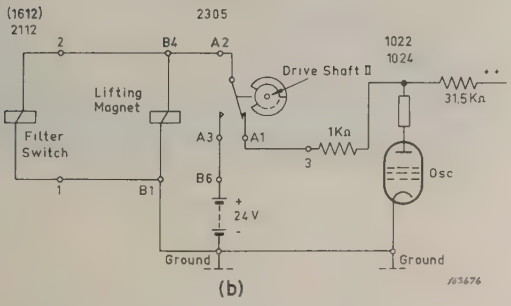


Fig. 6.16. Connection between instruments.
(a) Connection between remote control jacks.
(b) Electrical circuit.

Using a frequency-modulated oscillator or narrow band noise generator.
A suitable measuring arrangement is shown in Fig. 6.14.
In this instance, although not strictly necessary, it is recommended to employ the technique of selective signal reception, which ensures a much larger dynamic range for the decay curves owing to a reduction in the systems noise level.

Frequency Calibrated Paper. The measuring arrangement shown in Fig. 6.14 allows decay curves with a spacing of $\frac{1}{3}$ octave to be recorded automatically in the frequency range 25 Hz (c/s) to 20 kHz (kc/s). All the curves will be presented on a frequency calibrated chart with a length of 250 mm. The transmitting part of the equipment consists of the B & K Oscillator Type 1022 or 1024 and one or two loudspeakers. The receiving part is comprised of one of the B & K Condenser Microphones, the Spectrometer Type 2112 and the Level Recorder Type 2305. The signal frequency from the Oscillator should either be frequency modulated, the frequency and swing of the modulation being easily selected by two control knobs on the B.F.O. Type 1022, or narrow bands of noise from the Oscillator Type 1024 should be employed. In this manner a smooth reverberation curve will be recorded for each frequency at which measurements are carried out.
For recording the decay of the sound in the room the sound source has to

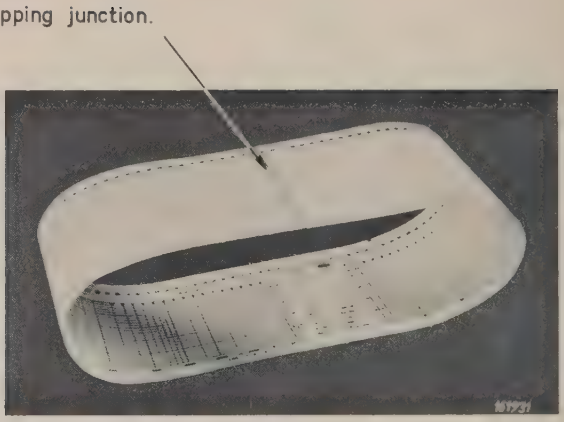


Fig. 6.17. Construction of paper loop. The dotted line illustrates the necessary ***overlap at the junction.***

be disconnected at definite intervals, this is achieved by stopping the oscillator in the B. F. O. To ensure that only the part of the measurement is recorded which is of interest, the writing pen should lift from the paper in the interval between two decays, and when selective reception is utilized, the filters in the Spectrometer should be switched in successively. The disconnecting of the sound source, the lifting of the pen and the switching of the filters in the Spectrometer can all be automatically controlled by a special switch in

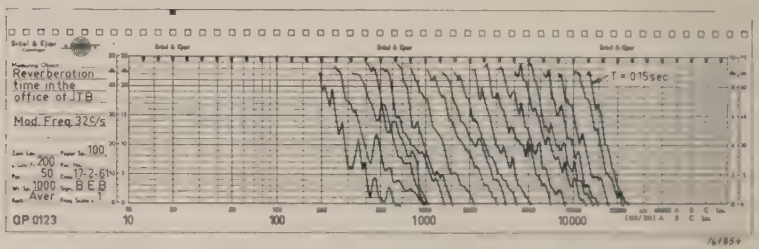


Fig. 6.18. Reverberation decay curves with a spacing of 1/3 octave (5 mm). ***Compressor arrangement used.***

the Level Recorder. (The Two-Channel Selector). The necessary connections between the different instruments are shown in Fig. 6.16. The connections to the respective Remote Control Jacks are shown in Fig. 6.16a, while Fig. 6.16b gives the electrical circuits for the remote controlling arrangement.
When placing a loop of 50 mm paper width (Fig. 6.17) in the Level Recorder

with a length of 495 mm (i.e. two chart lengths minus 5 mm; 5 mm being the distance between two perforated holes) it is possible to have the curves for the different frequencies placed with a spacing of ⅓ octave as shown in Fig. 6.18. By synchronizing the paper movement with the frequency scanning of the B. F. O. with the filter switching on the Spectrometer and with the switching off moment of the sound, the starting points of the decay curves will correspond to the center frequency of the respective filters represented by small squares on the top of the preprint of the recording paper, see Fig. 6.18. It is possible, to a certain degree, to keep the sound pressure level at the point of measurement independent of loudspeaker and room response by utilizing the compressor circuit of the B. F. O. as indicated in Fig. 6.14. This method ensures that all the decay curves commence at the same level on the recording paper.

Non-Frequency Calibrated Paper. When a larger spacing than 5 mm between the decay curves is desired (vide example in Fig. 6.19), the recording paper loop used in the Recorder has to be made accordingly shorter as the length of this determines the spacing. For example, a loop length of 490 mm gives 10 mm spacing between the curves. In such instances the recording has to be carried out on the lined recording paper, e.g. QP 0102, QP 1102 or QP 0402, and it is necessary to "mark" one or more frequencies on the paper. The marking can be readily done by means of the Level Recorder's EVENT-MARKER arrangement.

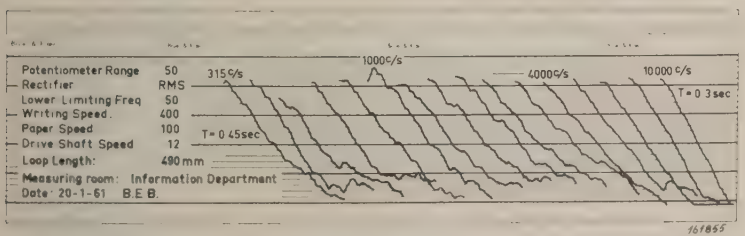


Fig. 6.19. Reverberation decay curves with a spacing of 10 mm. Compressor arrangement used.

Using a Wideband Random Noise Generator.
In this case bands of noise with constant percentage bandwidths are generated, and it is recommended to use a selective receiver which ensures a large dynamic range. However, it is also possible to dispense with the selective receiver, but then a greater power amplifier must be used, to obtain sufficient signal power from the loudspeaker to make the background noise insignificant. The electrical "transmitting" part of the system consist of a Band Pass Filter Set Type 1612 together with a Noise Generator Type 1402 as shown in Fig. 6.15. The impedances at the input and output terminals of the Filter Set

automatically match the B & K Noise Generator. By employing the Filter Set noise bands of ⅓ or 1/1 octave widths can be selected. It should be noted here, that when noise bands having constant percentage bandwidths are being used, such as ⅓ or 1/1 octave bands, the power output will increase proportional to frequency. If it is desired to utilize the same power output

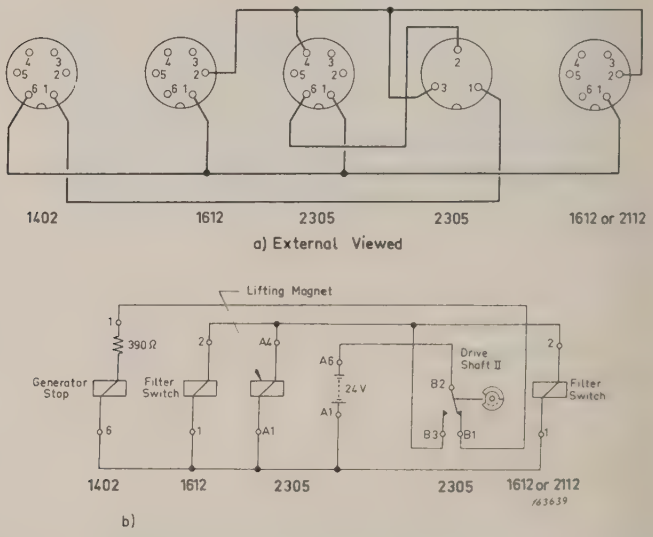


Fig. 6.20. (a) Connection between remote control jacks. (b) Electrical circuit.

in each band it is then necessary to "shape" the input spectrum to the filters so that it drops off with frequency at a rate of 3 dB/octave. This is provided for in the Noise Generator Type 1402 in that it can be switched to either produce a flat ("white") spectrum or a spectrum with a slope of —3 dB/octave. When reverberation measurements (or sound insulation measurements) are made in great assembly-halls, in factories, schools, or other "public places" it may be necessary, even if bands of noise are used for the measurements, to employ a power amplifier. The —3 dB/octave condition of the Noise Generator then allows the amplifier to be used with maximum efficiency during all the measurements. When it is desired to use frequency calibrated paper and automatic recording, the necessary connections between the different instruments are shown in Fig. 6.20.

Use of the Protractor SC 2361.

The Protractor has been designed to facilitate the determination of reverberation time from recorded decay curves on the 50 mm width paper. It is divided into four sections marked "75 dB 10 mm/sec.", "75 dB 30 mm/sec.", "50 dB 10 mm/sec.", and "50 dB 30 mm/sec.". When one of these four combinations of RANGE POTENTIOMETER and PAPER SPEED has been employed during the measurements, the reverberation time can be read directly in seconds.

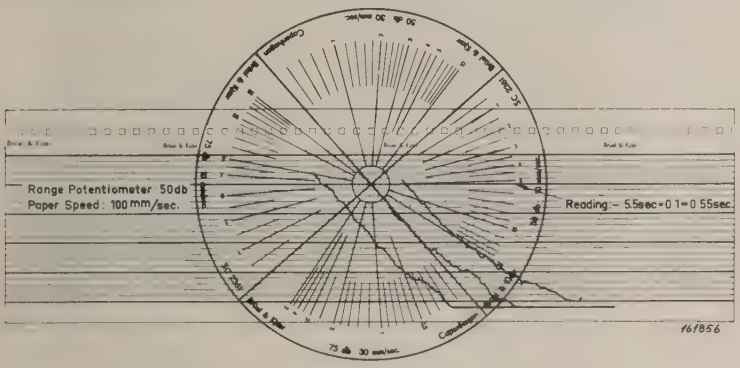


Fig. 6.21. Employment of the Protractor SC 2361.

1. The Protractor is held so that the printing is readable. The proper section is chosen and its left limiting line (thick diagonal) is placed on top of the portion of the recorded decay curve to be measured, and in such a manner that the centre of the Protractor coincides with one of the horizontal lines on the recording paper. Refer Fig. 6.21.
2. The reverberation time in seconds is then read on the scale at the point through which the horizontal line passes. Vide Fig. 6.21.

The decay curves should preferably be approximated into straight lines making it easier to determine the average slope.

If paper speeds other than 10 and 30 mm/sec. have been used, the reverberation times should be multiplied or divided by factors of 10.

Example.

50 dB Range Potentiometer.

Paper Speed 100 mm/sec.: Use the section "50 dB 10 mm/sec." and divide the measured result by 10, see also Fig. 67.

If the decay curves are recorded on 100 mm paper width, the results measured by the protractor have to be multiplied by 2.

Measurement of Acoustical Noise from Small Objects.

Measurement of noise levels and the determination of acoustical noise spectrograms from small objects such as domestic apparatus, small electrical

motors, fluorescent lamp mountings etc. is difficult, as the level of the noise to be measured is extremely low. In order to increase the acoustical effect from the objects, and reduce external disturbances, it is recommended that the objects are placed in a special oblique-angled measuring box making a small measuring room which has very hard sound-reflecting walls. A room with a volume of about 2 m^3 with walls, floor and ceiling constructed of 10 cm concrete, and internally covered with smooth hard tiles is very suitable. The reverberation time can easily be brought up to about 2 sec., and

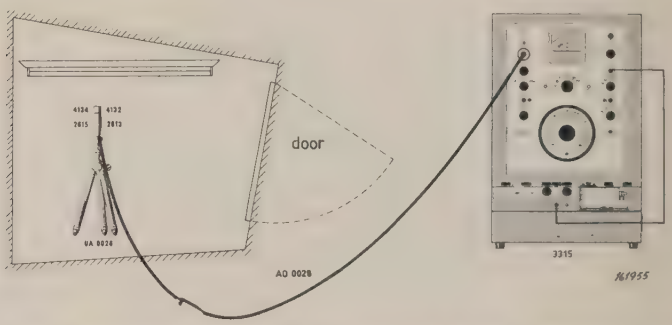


Fig. 6.22. Measuring arrangement for analysis of noise produced by small objects. In this case fluorescent lamps.

with the help of small resonators be held constant over a frequency range from 60—5000 Hz (c/s).

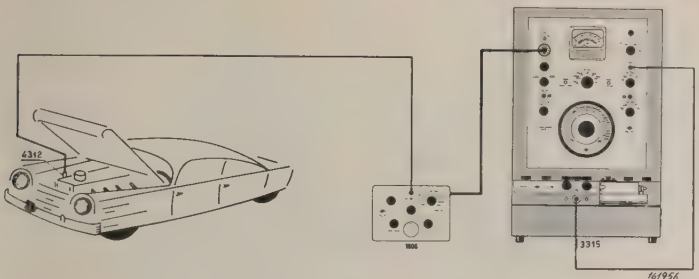
Fig. 6.22 shows a sketch of a practical measuring room designed as described above. For sound measurements in such a reflecting room the Condenser Microphone with Extension Cable AO 0027 (3 m), AO 0028 (10 m) or AO 0029 (30 m) should be used.

Vibration Measurements and Analyses.

On the spot measurements of vibrations in buildings, machinery, ships, etc. can be carried out by employing one of the B & K Accelerometer Sets, in conjunction with the Vibration Pick-up Preamplifier Type 1606. The output of the latter being fed to the input "Condenser Microphone" on the Spectrometer Type 2112.

When taking simple measurements, one of the Cathode Followers Type 2612, 2613, 2614 or 2615 combined with the respective Input Adaptor may be used as a preamplifier for the Accelerometer Set.

By employing the Vibration Pick-up Preamplifier the value of acceleration measured by one of the Accelerometers can be transformed into velocity or displacement. As the Preamplifier Type 1606 contains a small shaker table



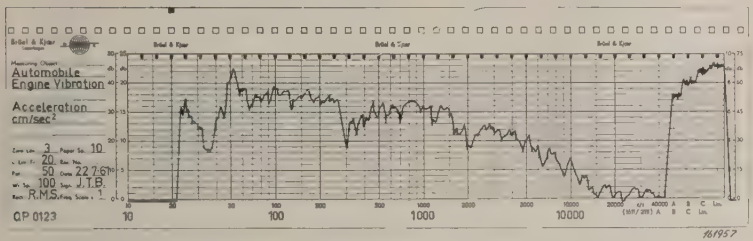


Fig. 6.23. Vibration measurement of automobile motor.

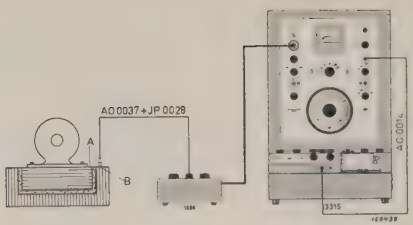
for the absolute calibration of the complete arrangement a reading in dB. with reference to this calibration, can thus be taken on the indicating meter of the Spectrometer Type 2112. When the measuring arrangement is combined with the Level Recorder Type 2305, an automatic recording of the analysis as a function of frequency can be carried out with respect to acceleration, velocity, or displacement of the vibration in question.

Fig. 6.23 shows a typical example of a set-up employing Accelerometer Type 4312, Preamplifier Type 1606, and Audio Frequency Spectrum Recorder Type 3315 for the measurement of vibrations of an automobile engine. Together with the set-up is shown the resultant spectrogram giving the acceleration as a function of frequency.

Fig. 6.24 shows the measurement of vibration on a motor foundation. The spectrogram gives the results of measurements taken at point "A" on the foundation, and at a point "B", the latter being outside the vibration-isolated foundation.

Measurements of Impact Sound.

The sound insulation of a floor against impact sounds is estimated by using a standardized impact sound generator such as the B & K Tapping Machine Type 3204 on the floor. The sound pressure level L in the room below is then measured in various frequency bands. (Vide Fig. 6.25 where two receiving



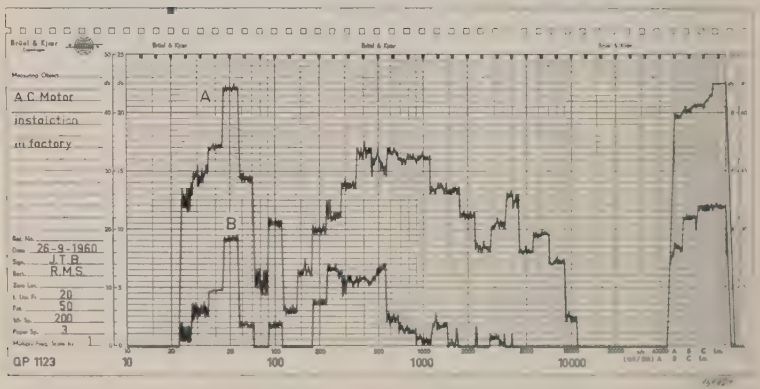


Fig. 6.24. Vibration isolation measurements.

systems are shown, one for recording and one for direct reading. In the proposed ISO standards R 140 C 1960 for these measurements, it is recommended to analyse with ⅓ octave filters for the estimation of the sound pressure. If the analysis is carried out with a filter comprising a narrower band than ⅓ octave an appropriate correction has to be made.

If it is desired to express the level by a single figure L_A, this can be calculated according to the standard, but additionally it is always recommended to take a spectrogram of the sound in the lower room as this spectrogram enables the acoustical quality of the floor to be assessed as a function of frequency. Vide Fig. 6.26.

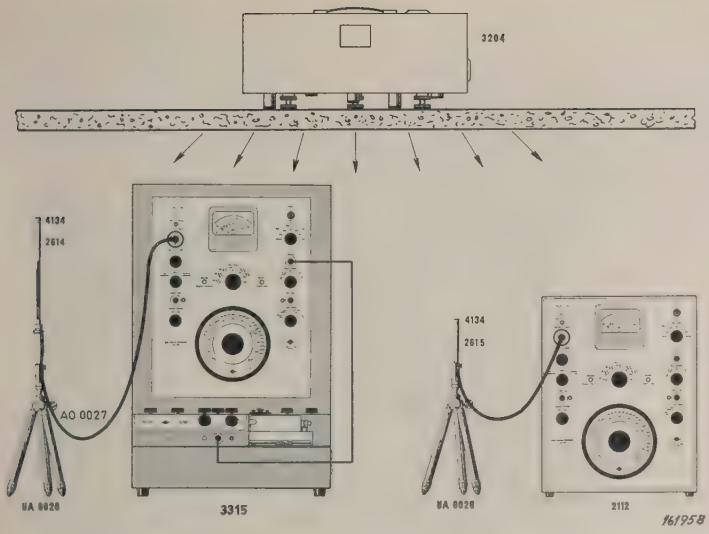


Fig. 6.25. Measuring equipment for impact sound measurements.

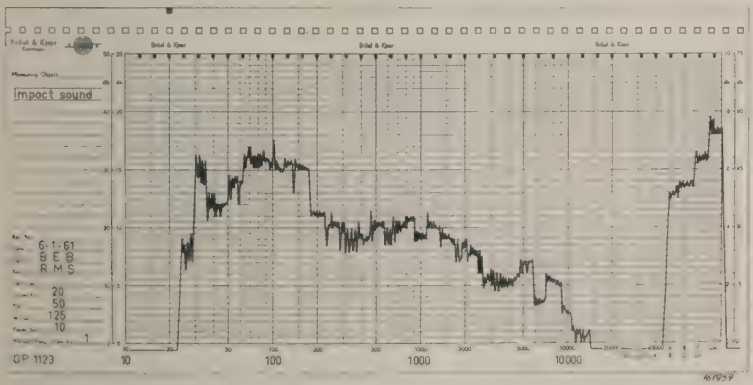


Fig. 6.26. 1/3 octave spectrogram obtained from impact sound.

Measurement of Airborne Sound Insulation with the Aid of White Noise.

Fig. 6.27 shows a handy and simple method for the measurements of airborne sound insulation of partition walls and floors in buildings. The measuring arrangement includes the Spectrometer and the B & K Level Recorder Type

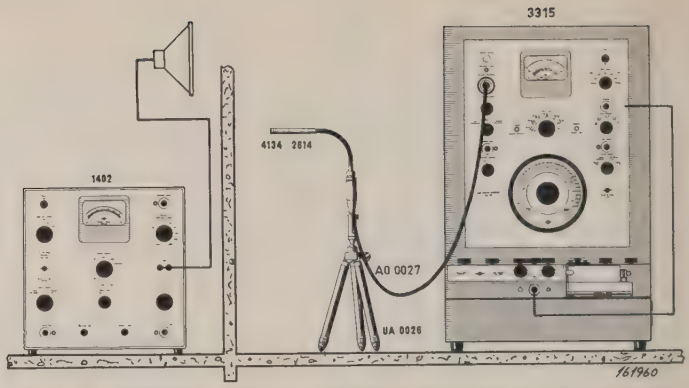


Fig. 6.27. Measuring set-up for analysis of airborne sound insulation.

2305 as well as the Noise Generator Type 1402, the latter providing that all the acoustical frequencies (20—20000 Hz (c/s)) are radiated in the transmitting room. The airborne sound insulation of the partition between room 1 and room 2 is measured by producing a high sound pressure level of noise in room 1, and then to measure the sound pressure level occurring in room 2. If the sound pressure level of the noise is recorded as a function of frequency first in room 1 and then in room 2, the sound pressure relationship between the two rooms can be estimated immediately from the difference between the two curves. The insulation quality of the partition, is then readily calculated when suitable corrections are made for the sound absorption in the receiving room.

The Level Recorder Type 2305 has a facility allowing it to stop automatically after moving the paper one chart length in either the forward or reverse direction. Also, when the paper has been reversed by one chart length, a new recording can be taken without losing the synchronization between the paper movement and the switching moment of the filters on the Spectrometer. It is thus seen that the second recording shown in Fig. 6.28 is easily taken on the same chart as the first.

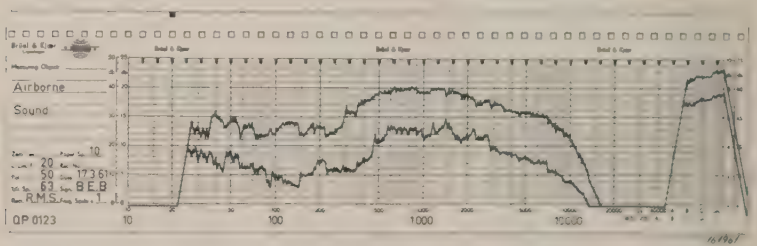


Fig. 6.28. Recorded spectrogram of airborne sound (1/3 octave analysis).

Absorption Measurements.

The sound absorbing properties of different materials may be evaluated from reverberation measurements, or a direct measurement of the absorption coefficient for zero degree sound wave incidence can be carried out with the Standing Wave Apparatus Type 4002. The standing wave method has proved to offer a quick and inexpensive measurement of the absorption coefficient of materials.

A brief description of the Standing Wave Apparatus is given in part Appendix in this book.

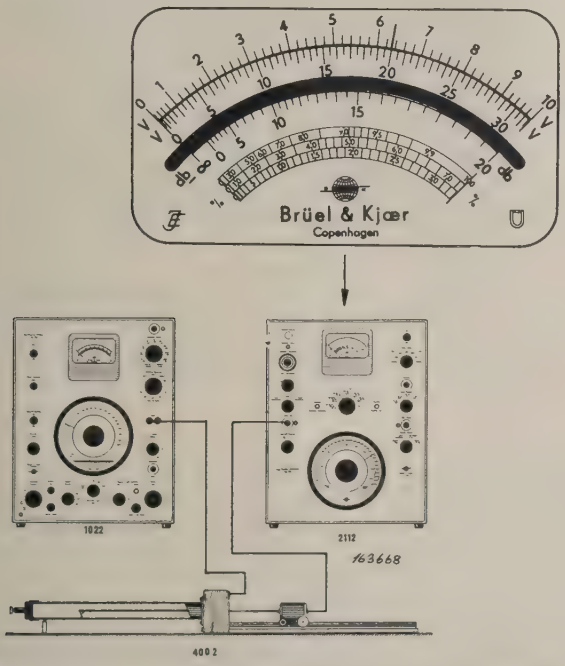


Fig. 6.29. Measuring equipment for the determination of acoustical absorption coefficient, employing Standing Wave Apparatus Type 4002.

In Fig. 6.29 is shown a measuring arrangement where a B & K Beat Frequency Oscillator Type 1022 supplies a signal frequency to the loudspeaker of the Standing Wave Apparatus, while the signal from the microphone is fed to the Spectrometer Type 2112.

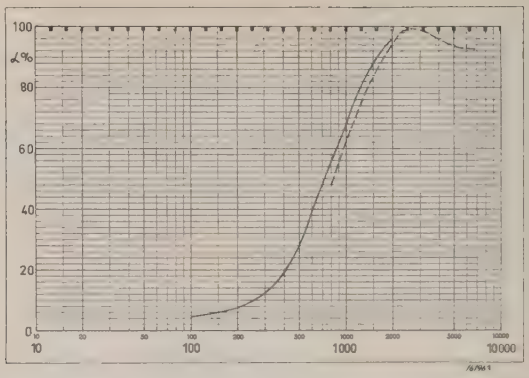


Fig. 6.30. Absorption coefficients of an insulation material measured with the Standing Wave Apparatus and plotted as a function of frequency.

To avoid the influence of noise and harmonic distortion, which may occur when the absorption coefficient of the sample to be tested is small, the measurement should be carried out selectively. The Spectrometer should therefore be used in its ⅓ Octave condition.

The indicating meter of the Spectrometer contains, in addition to the normal calibrations, three specially graduated scales, 0—100 %, 0—70 % and 0—30 %. These scales permit direct reading of the absorption coefficient in percent, and can be seen in the upper part of Fig. 6.29. Measurements carried out on a sample of insulation material are reproduced in Fig. 6.30.

Automatic Recording of Harmonics in Hearing Aids.

By employing an oscillator with a low distortion, such as the B & K Beat Frequency Oscillator Type 1022, along with the Spectrometer Type 2112, an equipment is obtained for measuring the harmonics produced in electronic or electro-acoustical devices. If the Spectrometer and the BFO are coupled to the B & K Level Recorder Type 2305 (as in the A.F. Response and Spectrum Recorder Type 3332), the measuring arrangement can now automatically record the harmonics of the device under investigation on frequency calibrated paper. A very common use of this combination is in the testing of frequency characteristics associated with, and harmonics produced in, hearing aids. A measuring set-up for this purpose is sketched in Fig. 6.31 .

Usually the distortion produced in the electronic part of a hearing aid (the hearing aid amplifier) is small compared with the distortion caused by the electro-acoustical transducing elements. The measuring arrangement shown includes for this reason the electro-acoustical system of the hearing aid.

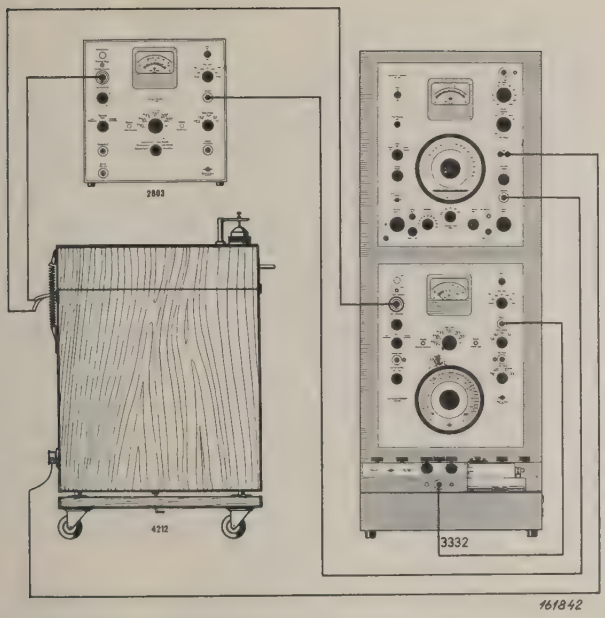


Fig. 6.31. Measuring arrangement for automatically measuring frequency characteristics and harmonic distortion of hearing aids.

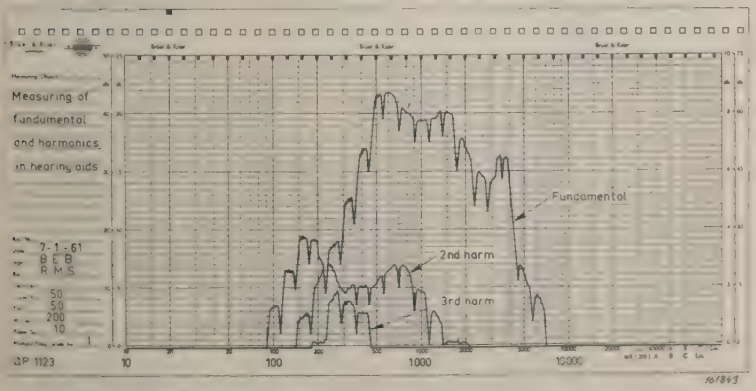


Fig. 6.32. Typical recording of frequency characteristic ("Fundamental") and harmonic signals in a hearing aid.

To measure the hearing aid under free-field conditions it has to be placed in the Hearing Aid Test Box Type 4212. A brief description of this Test Box is to be found in part Accessories of this book.

With the Test Box it is possible to measure the overall characteristics of the device with relation to the acoustical input and output. In the measuring arrangement sketched, the Microphone Amplifier Type 2604 is used as "compressor amplifier", i.e. it is used to amplify the output voltage from the regulating microphone in the Test Box. From the Microphone Amplifier the voltage is fed to the compressor input of the B. F. O. By this arrangement the sound pressure level in the Test Box chamber at the diaphragm of the regulating microphone (i.e. at the microphone of the hearing aid) can, in addition, be measured by this Amplifier.

In Fig. 6.32 are given the recorded results of measuring the fundamental together with the harmonics produced in a hearing aid. The harmonics are measured by setting the filter switch on the Spectrometer so that it runs ahead of the frequency scanning of the BFO, the selected space difference being in accordance with the harmonic which is going to be measured.

By means of the facility included in the Level Recorder Type 2305, which allows the recording paper to be reversed by one chart length without losing the synchronization between the BFO and the Spectrometer, the harmonics are readily recorded on the same chart as the fundamental.

Analysis of Transients.

An interesting application of the Audio Frequency Spectrometer Type 2112 is the analysis of transients, which makes it possible to obtain the

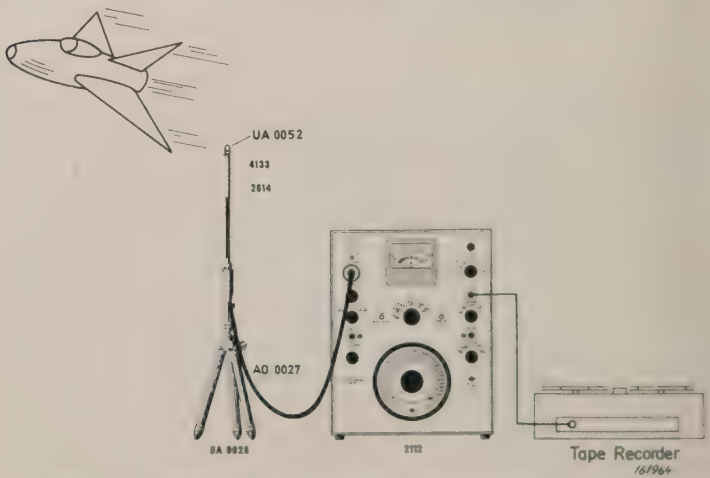


Fig. 6.33. Measuring equipment for recording of noise transients.

transient level, not only as a function of time, but also as a function of frequency. This type of analysis has proved to be of considerable value when noise transients from rockets, guided missiles, low flying aircraft, motor vehicles, etc. are investigated. In addition, it is often desired to obtain the "amplitude-frequency-time" relationship of the noise produced by periodically worked machinery such as drilling machines and large Diesel engines.
When acoustical transient phenomena are investigated, measuring arrangements as shown in Figs. 6.33 and 6.34 can be employed. The receiving part, Fig. 6.33 consists of one of the B & K Condenser Microphones, the Spectrometer and a tape recorder. To avoid distortion of the signal, the quality of the tape recorder should be high.
To obtain a reference signal on the tape, the Pistonphone Type 4220 or the Noise Source Type 4240 can be used. (Reference can be made to the respective manuals for these devices).
After the recording of the transient is carried out, the analysis of the noise on the tape can be made at any time and place. A measuring set-up as shown in Fig. 6.34 can be employed, enabling the results to be recorded both on non-frequency calibrated and frequency calibrated paper. If the tape with the recorded noise is not long, it can simply be joined as a loop, so that it can run continuously on the tape recorder.

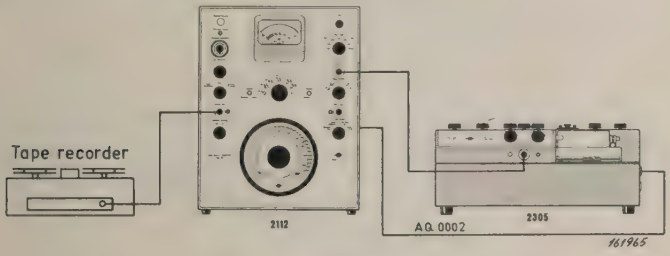


Fig. 6.34. Layout for analysis of a tape recording.

If a more portable equipment is required, the Spectrometer could be substituted by a B & K Microphone Amplifier Type 2604 combined with the Band-Pass Filter Set Type 1612. With such an arrangement the Microphone Amplifier is used in place of the Spectrometer during recording of the signal, whereas when analysing the Microphone Amplifier and Band-Pass Filter Set are used in combination.

Recording on Non-Frequency Calibrated Paper.*) By means of a contact arrangement on the tape recorder the filter switching on the Spectrometer

*) Three different types of recording paper, QP 1102, QP 0102, and QP 0402, are available.

can be controlled, and in a manner that a new filter is switched in for each rotation of the loop.
The Event-Marker on the Level Recorder can also be controlled from the same contact arrangement on the tape recorder, so that a mark on the paper is obtained where the switching from one filter to the next is carried out. A recording showing the amplitude of the noise as a function of time can now be carried out automatically for each filter in succession.

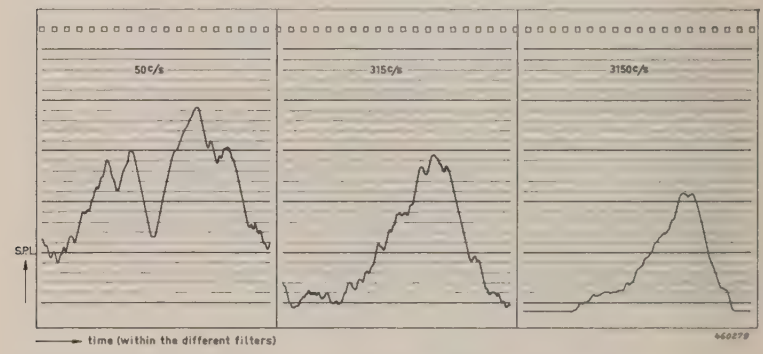


Fig. 6.35. Noise transient from an accelerating 150 c.c. motor. Analysed with three different 1/3 Octave Filters. Paper Speed 10 mm/sec.

By choosing a suitable paper speed on the Level Recorder (according to the time it takes for one loop rotation on the tape recorder), the absolute amplitudes of the noise transient can be read on the recording when the signal is compared with the reference signal recorded on the tape. In Fig. 6.35

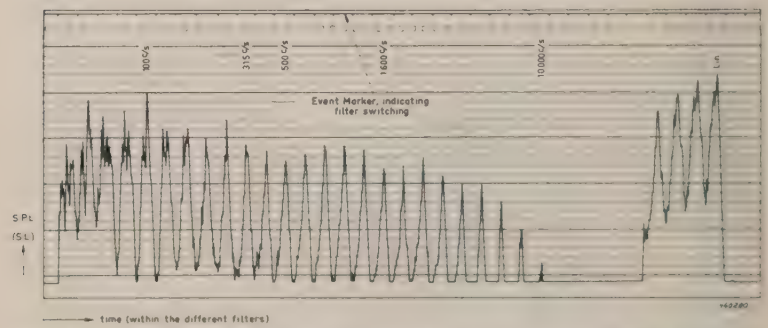
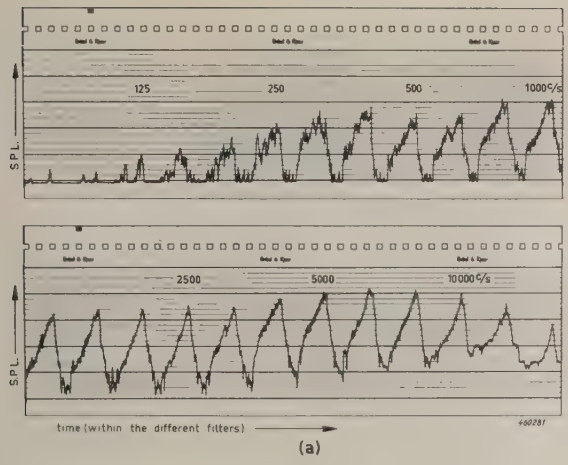


Fig. 6.36. Complete spectrogram of noise from an accelerating 150 c.c. motor. Paper Speed 1 mm/sec.



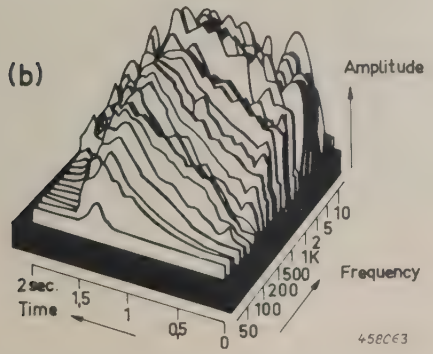


Fig. 6.37. Analysis of transient:—
(a) Passing motor-cycle suddenly halting.
(b) Item (a) represented three-dimensionally.

the amplitudes in a noise transient are shown, when filtered with three different ⅓ octave filters. From the recordings taken for each filter, a three-dimensional graph can be made, showing the amplitudes as a function of frequency and time, vide Fig. 6.37a. When a relatively low paper speed is chosen on the Level Recorder, the maximum amplitudes can be observed as a function of frequency, vide Fig. 6.37. By the markings created by the Event Marker, the frequencies (relative to their different filters) can be indicated.

*) Three different types of recording paper, QP 1102, QP 0102, and QP 0402, are available.

Recording on Frequency Calibrated Paper*). The recordings can be made on frequency calibrated paper. In this case the switching of the filters should be controlled from the Level Recorder and synchronization between paper movement and filter switching has to be carried out as described under "Operation" in this book. The length of the tape has to be adjusted so that the time it takes for one loop rotation corresponds exactly to the time between two filter switchings. When properly adjusted the switching of the filters will take place at the same point on the tape for each revolution.
In Fig. 6.38 is shown a spectrogram taken as described. The noise signal on the tape here covers only 50 % of the total loop length, which can be seen on the recording.

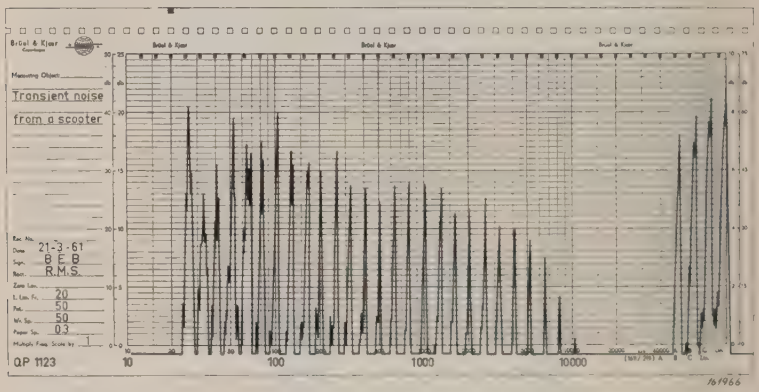


Fig. 6.38. Noise from an accelerating scooter motor. 1/3 octave analysis.

Appendix

Influence of Phase Distortion on Complex Signals.

Common amplifiers will always give a greater or lesser degree of phase distortion at their low and high frequency limits. The distortion will normally become perceptible about a decade higher than the lower frequency limit and about a decade lower than the higher frequency limit. Vide Fig. 1.15, page 29.

The phase distortion of an amplifier has no influence on the majority of its applications as long as the signal is a pure sine wave or pure sine waves with no phase relation, in other words, when the distinct frequencies do not comprise the harmonics of a signal. If a signal with such a character is rectified and fed to an indicating circuit enabling measurement of true r.m.s., average or half peak-to-peak value of the signal, any possible phase distortion will have no influence on the measured result. On the other hand, if the signal has a complex periodic character and thus contains harmonics with a certain phase relationship (as is the case, for example, with a square-wave or triangular signal) the signal shape will be distorted when treated in an amplifier which gives phase distortion. However, the number of harmonics and their original amplitudes are unchanged in the phase distorted signal, presuming that the amplitude vs. frequency characteristic of the circuit is practically straight in the range of the signal frequency contents. Due to the wave shape distortion the following should be noted when a signal containing harmonics is applied to a rectifier circuit which detects the true r.m.s., average or half the peak-to-peak:—

Measuring R.M.S.: This is by far the most important factor in the majority of investigations. When using this characteristic of the indicating circuit, the phase relationship of the different components in the signal has no influence. **Therefore, by measuring a phase distorted signal with an r.m.s. indicating circuit, the same value will be read as for the undistorted signal.**

Measuring Average: In this case the arithmetic average value of the signal deviates from the value of the original signal when phase distorted.

Measuring Peak: When utilizing the half peak-to-peak property of the indicating circuit a considerable deviation from the original value is measureable when the signal is phase distorted.

Actual Deviations in RMS, Average and Peak Reading. To illustrate the deviation in meter reading versus frequency caused by phase distortion, measurements were carried out when a symmetrical square-wave signal was

fed to the Spectrometer. In Fig. A.1b typical results from the measurements are reproduced. The curves are related to the response obtained from a sine-wave signal, i.e. the read values will be the deviation from the particular sine-wave amplitude vs. frequency characteristics. The r.m.s. reading shows an increase at the highest frequencies which is due to an increase in the Amplifier's frequency response beyond the high frequency limit (45000 Hz (c/s)).

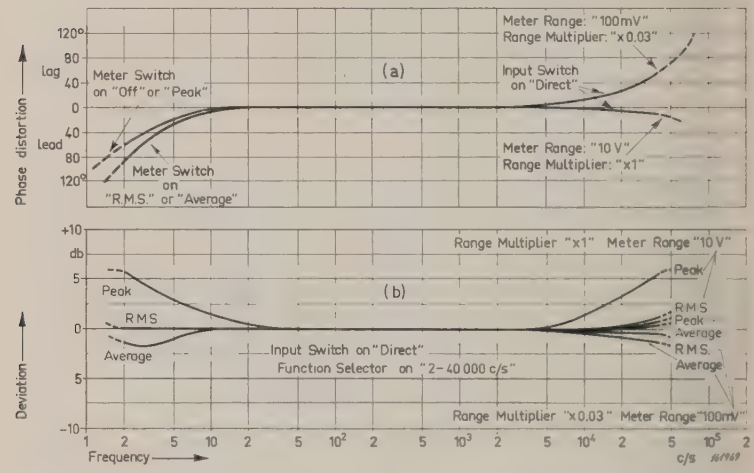


Fig. A.1. Typical deviation in r.m.s. average and peak reading from a symmetrical square-wave signal with the Spectrometer phase response as comparison.
(a) Phase response of Spectrometer.
(b) Deviation in reading.

For the purpose of illustrating the phase distortion influence, the phase response of the Spectrometer is shown in part (a) of Fig. A.1. From the graph is noted that at the high frequencies the phase distortion is, to a certain degree, dependent on the setting of the attenuators METER RANGE and RANGE MULTIPLIER. The two curves shown give the highest variation in phase response for the possible combinations of the two attenuator positions.

Shape Distortion of Signal with Harmonics. In Fig. A.2 is shown the influence of phase distortion of a symmetrical square-wave signal when treated in the Spectrometer and measured at the output RECORDER. Fig. A.2a gives a distorted 2 Hz (c/s) signal corresponding to the low frequency limit. Fig. A.2b illustrates a 50 Hz (c/s) signal, the shape of which will be equal to the calibration voltage (Ref.) of the apparatus when it is powered from a line voltage

with a frequency of 50—60 Hz (c/s). As Fig. A.2c shows, no phase distortion of the square-wave signal is present when its fundamental is around 1000 Hz (c/s). At the highest frequency, however, phase distortion is again perceptible, which can be seen on Fig. A.2d, where the distortion on a 40 kHz (kc/s) signal is reproduced. In the latter case the METER RANGE has been in position "10 V" and RANGE MULTIPLIER in position × 1.

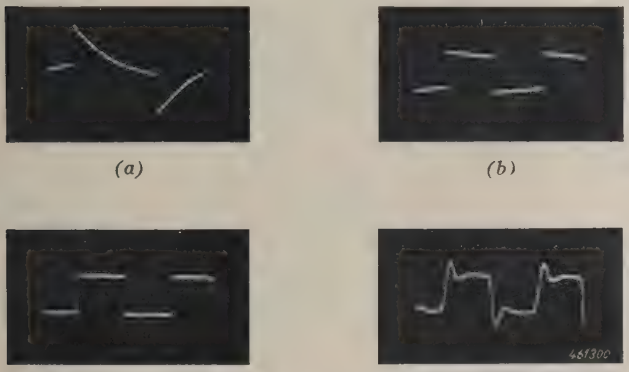


Fig. A.2. Typical shape distortion of a symmetrical square-wave treated in the ***Spectrometer.***
(a) 2 Hz (c/s)
(b) 50 Hz (c/s)
(c) 1 kHz (kc/s)
(d) 40 kHz (kc/s).

Specification

FREQUENCY CHARACTERISTICS:

"Linear": 2 Hz (c/s)—45000 Hz (c/s) within ± 0.5 dB relative to 1000 Hz (c/s).

5 Hz (c/s)—20000 Hz (c/s) within ± 0.3 dB relative to 1000 Hz (c/s).

Band Pass Filters: 33 filters of ⅓ octave bandwidth, 3 dB, center frequencies 25 Hz (c/s) to 40000 Hz (c/s).

11 filters of 1/1 octave bandwidth, 3 dB, center frequencies 31.5 Hz (c/s) to 31500 Hz (c/s).

Selectivity: ⅓ octave filters, approximately 50 dB at 1 octave from center frequency.

1/1 octave filters, approximately 35 dB at 1 octave from center frequency.

Deviation in Pass Band: Within ± 0.5 dB for ⅓ octave, and ± 1 dB for 1/1 octave filters, ± 2 dB for the 31.5 and 63 Hz (c/s) filters.

Weighting Networks: "A", "B" and "C", frequency response of Spectrometer inclusive of the Condenser Microphone Type 4131 or 4133 in accordance with the proposed IEC standards for Precision Sound Level Meters. (Helsinki 1961).*)

"Lin" gives linear range 20—45000 Hz (c/s). Cuts off by maximum 18 dB per octave below 20 Hz (c/s).

ATTENUATORS:

METER RANGE: 20 dB between steps.

Within ± 0.15 dB relative to position "10 mV", at 1000 Hz (c/s).

*) Vide passage "Description", page 22.

RANGE MULTIPLIER: 10 dB between steps.
Within ± 0.1 dB relative to position "× 0.01", at 1000 Hz (c/s).

INPUT IMPEDANCES:

"Direct": 2.2 Megohm parallel with 30 $\mu\mu$F.

"Input Potentiometer": 0.7—1 Megohm approximately the parallel capacity being dependent on the setting.*)

"Condenser Microphone": 2.2 Megohm parallel with 30 $\mu\mu$F.
(270—700 Megohm parallel with 2.5—3 pF obtainable when one of the B & K Cathode Followers is utilized).

METER:

Meter Rectifier Circuits, Accuracy:)** "RMS", ± 0.5 dB for crest factors up to 5.
"Average", ± 0.1 dB of the read value.
"Peak" (half peak-to-peak) ± 0.2 dB of the read value.

Meter Scale: ± 1 % of full deflection for "RMS", "Average", and "Peak".

Meter Damping: "Slow" and "Fast" both in accordance with the proposed IEC standards for Precision Sound Level Meters (Helsinki 1961).
The meter is perfectly protected against overload.

CALIBRATION VOLTAGE: Built in, mains frequency square wave.
Within ± 0.03 dB for ± 10 % deviation of the power voltage.

SENSITIVITY: Maximum 100 μV and minimum 1000 V for full deflection on the indicating meter.

DISTORTION, INPUT AMPLIFIER: Within 0.1 % in the frequency range 5—45000 c/s, when voltage on FILTER INPUT EXTENSION FILTER does not exceed 1 V r.m.s., sine-wave, and load is formed by the built-in filters or an impedance higher than 500 ohm. With a load impedance higher than 5 kΩ the voltage can be 10 V r.m.s. sine-wave.

*) Vide passage "Description", Input Circuit, page 14.
**) Vide passage "Description", page 25.

OVERLOAD INDICATOR: Indicates by red light when output voltage of input amplifier section exceeds 4.5 V peak approx.

SIGNAL/NOISE RATIO, (2—45000 c/s) (as Linear Amplifier):)** Better than 60 dB with RANGE MULTIPLIER switch in position "× 1, 0 dB", full deflection on the indicating meter and short-circuited AMPLIFIER INPUT. The ratio is made the same numbers of dB smaller as the gain is increased in dB by the RANGE MULTIPLIER relative to the said position.

NOISE, (2—45000 c/)

Input Amplifier: Referred to the input at maximum gain, 40 dB.
Approximately 5 μV with short circuited input.
Approximately 15 μV with open input.

Output Amplifier: On RECORDER output.
Approximately 10 mV with RANGE MULTIPLIER in position "× 1".
Approximately 20 mV with RANGE MULTIPLIER in position "× 0.01".

OUTPUT AT THE TERMINAL "RECORDER":

Voltages: 8—10 V for full deflection on the meter scale. Maximum available peak voltage approximately 45 Volts.

Output Impedance: Smaller than 50 Ω in series with 24 μF.

Load Impedance: Highest possible.
At 3 kΩ, 15 V peak available with METER SWITCH on "Off".
At 8 kΩ, 45 V peak available with METER SWITCH on "Off".

TERMINAL "FILTER INPUT - EXTENSION FILTER":

Voltage: 1 V Max: for full deflection on indicating meter. (Spectrometer set as linear amplifier.)
75 V DC approx. independent of indicating meter deflection.

Output Impedance: 10 Ω approximately.

**) Vide Fig. 1.16 on page 30.

TERMINAL "FILTER OUTPUT":

Input Impedance: 1.5 Megohm paralleled by 40 pF approximately.

STABILITY: Better than ± o.3 db for a deviation of ± 10 % of power supply voltage.

REMOTE CONTROL: The filter switching can be remotely controlled by a single poled switch in series with a 24 V DC supply (180 mA). For further information vide passage "Description", page 23.

POLARIZATION VOLTAGE: The polarization voltage for the Condenser Microphone Cartridges can be adjusted between 150 and 250 Volts.

TUBES: ECC81 (12AT7) — ECC83 (12AX7) — EF94 (6AU6) ECF82 (6U8) — EZ90 (6X4) — OA2 - OB2.

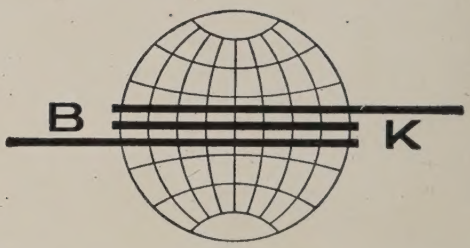
POWER SUPPLY: 100—115—127—150—220—240 Volts AC, 50—400 Hz (c/s). Power consumption is approx. 50 Watts.

DIMENSIONS: The Spectrometer is delivered in three versions: as Type A, B or C. Type A has a lightweight metal cabinet. Type B is a Type A instrument housed in a mahogany cabinet with handles and lid. Type C is a Type A instrument supplied with a frame for 19″ rack mounting.

Dimensions, Type A:
Height: 48 cm, Width: 38 cm, Depth: 20 cm.
Weight: 25 kg (55 lbs).

ACCESSORIES INCLUDED:

1 power cord
1 control cable A 0002
4 screened plugs JP 0018
Various fuses and lamps.



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